Science Library

NOV 5 1947

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Vol. 1 JULY–SEPTEMBER, 1947 No. 3

The Biology and Economics of the Beverage Industry
RALPH H. CHENEY

Taro—With Special Reference to Its Culture and Uses in Hawaii
AMY B. H. GREENWELL

Veneers and Plywood—Their Manufacture and Use
ELLWOOD S. HARRAR

Henbane—Healing Herb of Hercules and of Apollo
GEORGE M. HOCKING

Agar—A Pre-War Japanese Monopoly — HAROLD J. HUMM

Cinchona Plantation in the New World — F. R. FOSBERG

Technical Literature Review

Kenaf—Fiber-Plant Rival of Jute — JULIAN C. CRANE

Utilization Abstracts

By the editor

Soybeans. Sesame. Brazilian Timbers and Medicinals. Bamboo Pulp. Cork Oak in Maryland. Charcoal. Oiticica Oil. Tanning Materials. Spanish Essential Oils. Hemp.

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Founded, managed, edited and published by

EDMUND H. FULLING

at

The New York Botanical Garden

Advisory Editors

DR. RALPH HOLT CHENEY
Brooklyn College

DEAN GEORGE A. GARRATT
School of Forestry, Yale University

DR. ALBERT F. HILL
Harvard University

DR. WILLIAM J. ROBBINS
The New York Botanical Garden

DR. E. E. STANFORD
College of the Pacific

DR. H. W. YOUNGKEN
Massachusetts College of Pharmacy

Economic Botany is published quarterly. Subscription price per annual volume everywhere is $5.00; price per single copy is $1.50. Subscriptions and correspondence may be sent to the office of publication, N. Queen St. and McGovern Ave., Lancaster, Pa., or to Economic Botany, The New York Botanical Garden, New York 58, N. Y., and checks should be made payable to Economic Botany. Typescripts should be double-spaced. Photographs will be considered only if of high photographic quality.

Published Quarterly one volume per year, January, April, July and October, at North Queen Street and McGovern Avenue, Lancaster, Pa.

Entered as second-class matter March 12, 1947, at the post office at Lancaster, Pa., under the act of March 3, 1879.

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

VOL. 1 JULY–SEPTEMBER, 1947 No. 3

THE BIOLOGY AND ECONOMICS OF THE BEVERAGE INDUSTRY. *Ralph H. Cheney* 243

TARO—WITH SPECIAL REFERENCE TO ITS CULTURE AND USES IN HAWAII. *Amy B. H. Greenwell* 276

VENEERS AND PLYWOOD—THEIR MANUFACTURE AND USE. *Ellwood S. Harrar* 290

HENBANE—HEALING HERB OF HERCULES AND APOLLO. *George M. Hocking* 306

AGAR—A PRE-WAR JAPANESE MONOPOLY. *Harold J. Humm* 317

CINCHONA PLANTATION IN THE NEW WORLD. *F. R. Fosberg* 330

KENAF—FIBER-PLANT RIVAL OF JUTE. *Julian C. Crane* 334

Utilization Abstracts

By the editor

Page 275—Soybeans. *Page 289*—Sesame. Brazilian Timbers and Medicinals. *Page 316*—Bamboo Pulp. Cork Oak in Maryland. Charcoal. *Page 329*—Oiticica Oil. *Page 333*—Tanning Materials. *Page 350*—Spanish Essential Oils. *Page 351*—Hemp.

The Biology and Economics of the Beverage Industry

Cocoa, coffee and tea, world-wide in their use, and yerba matte and guaraná in South America are the great non-alcoholic beverages of plant origin which owe their stimulating qualities to their content of caffein or caffein-like alkaloids.

RALPH H. CHENEY
Brooklyn College

Introduction

BEVERAGES constitute the most immediately essential category of the human diet because complete elimination of liquid from the human body, water specifically, results in death more quickly than the withdrawal of any other single substance. It is not surprising, therefore, that beverages form the basis of a major industry in every part of the world. Water and milk were the original and have always been universal beverages, but they will not be considered here, for they are not directly of plant origin. All other drinks are derived from plant life which is the source of the beverage industry. The human mouth contains 256 taste buds possessing a high degree of sensitivity, because of which, together with the fact that the sense of smell is inter-related almost inseparably with taste interpretation, it is not difficult to account for man's persistent interest in varying his beverage sources. The human race has unceasingly sought drinks which are both palatable and stimulating, and this quest for satisfaction has led to the utilization of native plant species for beverages in every corner of the globe. The result has given us two great categories—the alcoholic and the non-alcoholic. Some members of each division have proven to be harmful, such as those containing opium or cocaine, or certain especially destructive types of alcoholic liquors, such as pulque.

Although native people everywhere have found plants which meet their beverage cravings for refreshment and comfort without undesirable after-effects, a few species, namely, cocoa, coffee and tea, have proven themselves so extraordinarily satisfying in palatability and stimulation that their use has become world-wide. These have left the so-called "other beverages" in a decidedly secondary place in the esteem of even local populations. Space necessitates the omission, in general, of data regarding wines, beers (malt liquors) and distilled liquors from the current discussion. Our subject, then, is limited to the three most important non-alcoholic beverages—tea, coffee and cacao (chocolate and cocoa); to other beverages of major local importance, such as maté, guaraná, naranjilla and a few others having considerable consumption within a given country; to fruit juices briefly; and to the so-called soft drinks.

In the United States coffee is served in 94% and tea in 87% of the homes. Cocoa or chocolate as a beverage is served to a lesser extent, but chocolate is the number one flavor of the country. Soft drinks are consumed in the U. S. at the rate of 50,000,000 bottles a day,

and are all highly energizing, due to their high dextrose content; in addition, the cola drinks are stimulating also because of their caffeine. Soft drink production, therefore, is a major business enterprise in the economic life of the nation.

consumed daily in such volume by the majority of the populations of the earth that they constitute two of the chief items of international commerce. The success of these crops annually in the production areas determines the economic prosperity of the entire country

FIG. 1. Four common soft drinks, representing a major part of the American beverage industry based upon the utilization of plant products and consumed in the United States to the extent of 50 million bottles per day. (*Courtesy Corn Products Refining Co.*)

Even a casual survey of the multitude of beverages throughout the world will show indisputably that the most universally popular ones contain caffeine or closely related compounds. These are tea, coffee, cocoa and chocolate, yerba matte and guaraná. The first two are

in which they are produced. Tea consumption leads in the Orient, in the United Kingdom, in other English possessions and in the U. S. S. R., but, in general, coffee is the more popular elsewhere.

The eastern hemisphere produces the

tea and the western hemisphere now furnishes 5/6 of the world's coffee. Brazil produces over half of this latter total, and Colombia is the largest producer of mild coffees. In value coffee is the chief export crop and constitutes a higher percentage of the total exports from Brazil (32%), Colombia (58%), Costa Rica (53%), El Salvador (76%), Guatemala (45%) and Haiti (37%) than any other product. It ranks high in 14 of the 20 Latin American Republics.

In terms of plant geography it is interesting to note that ecological conditions of soil and climate have determined the areas of production more than any other factors. Tea, native of the Orient, has remained largely in its original and adjacent geographic homelands. Coffee, native of Africa and India, has been developed largely in the western hemisphere, especially in South America, where none of the 40 species originated. Of the estimated total of 5¼ billion cultivated coffee trees in the world, over four billion are in South America. Cacao, native of North America, reaches its maximum production in the Gold Coast of Africa.

The flavor characteristics of the commercial types of all these beverage sources are due, to a great degree, to the ecological combinations under which they are grown. Tea-testers can recognize the source of tea with amazing accuracy; and lowland and highland grown coffees also readily reveal their identity by the body, acidity and flavor of the cup beverage. Production of maté and guaraná has remained in their native habitat of Brazil and adjacent territory. Yerba matte has a "strong" or "mild" flavor, according to the soil composition and atmospheric conditions under which it is produced. It is obvious, therefore, that plant geography, agricultural phases of botanical science and the effect of these beverages upon the physical health of the consumers, together with the problems of international economy, form a complex network of major importance to the well-being of the world's populations.

Tea

Production and Consumption. For 16 centuries tea drinking has been on the increase until world production today is annually two billion pounds. It is still cultivated largely in its original geographic distribution in the Orient. China is the No. 1 producer, but India is the No. 1 exporter and the No. 2 producer. Ceylon is No. 3 in tea crop production but No. 2 as a source of U. S. tea. U. S. imports have reached nearly 100 million pounds annually (98,962,516 lbs. in 1940 and 83,814,569 in 1945). In 1946 tea inventories in the U. S. were six to eight million pounds (9/10 Black and 1/10 Green tea) higher than for any pre-war year. Tea is so important to the American palates of the U. S. that in 1943 the Federal government took charge of the importation of it as a war measure and received a quota ration from Ceylon under the British-American allocation agreement. We consume over one million pounds per week, and in 1940 we paid over $20,000,000 for the 99 million pounds imported. In addition to the major production areas of China, India, Ceylon, the Netherland Indies and Japan, tea is now grown on smaller acreages in the Union of South Africa which supplies itself with only 1/20 of its requirements, in British India, British Malaya, Southern Rhodesia, Kenya, Uganda, Mauritius and Nyasaland.

Tea is also cultivated in Brazil, Russia, Natal and Guatemala. About a century ago in the United States tea as a crop was tried successfully from the agricultural standpoint but failed economically. Brazil has grown some for over a hundred years. Brazilian tea represents hybrid types of Indian (Assam) and Chinese varieties. Eight firms in that country trade in the production from

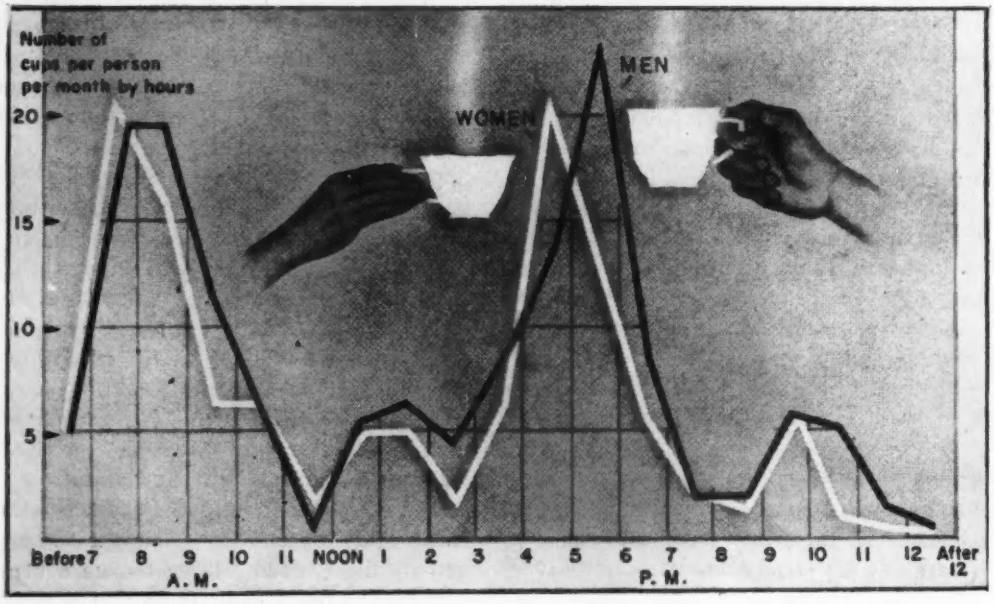


FIG. 2. (*Upper*). Mr. George F. Mitchell, left, and Mr. Raymond B. Partridge, right, in the tea-testing laboratory of the General Foods Corporation, Maxwell House Tea Division. FIG. 3 (*Lower*). Chart showing the relative consumption of tea during the day by men and women in Great Britain, a great tea-drinking nation. (*Chart by V. Puglisi, courtesy Time Magazine.*)

two million tea plants yielding over 50,000 kilos of finished tea, and the largest tea plantation in Brazil is "Fazenda do Tesoureiro". Brazilian tea has a high tannin content (15.4%) which is desirable because good tea leaves contain over 30% water-soluble substances, and a high tannin content gives body. Brazilian tea types are the equivalent of Broken Orange Pekoe, Orange Pekoe, Pekoe and Broken tea, consisting of first leaves and bud, second leaves, third leaves and a mixture of broken leaves of types of the first three types, respectively. Brazilian tea exports are increasing, as indicated by 71,776 kilos in 1939, 91,507 kilos in 1940, and 134,163 kilos in 1941. During World War II tea became a naturalized citizen of Guatemala where commercial plantations have been developed in a favorable soil and climate environment, and there is the possibility of great expansion in that area if the need arises.

History. A probable origin of tea as a beverage is, according to legend, due to the experience of a Chinese philosopher who was using twigs from a tea bush (tree) as firewood. Some of the leaves fell into the pot of boiling water and sent up a delicious aroma. He tried the brew and enjoyed it, and tea as a beverage was born. The Dutch brought tea to Europe in 1610. It was introduced into England by 1664, and today London is the tea capital of the world, importing 450 million pounds annually. In 1690 Benjamin Harris and Daniel Vernon were licensed there to sell "Coffee, Tee and Chucaletto". The relative number of cups of tea consumed by the average man and woman of Britain between 7 A.M. and midnight shows early morning and late afternoon-early evening to be the great tea hours of this tea-drinking nation where the average person drinks five cups a day (Fig. 3).

Tea was first advertised for sale in Boston in 1714, and in 1728 it was offered to the New York public. When tea was first used in Salem, Massachusetts, it was boiled in an iron kettle, the liquor drained off and the leaves eaten with butter and salt; the infusion was also consumed as a beverage. This early practise was somewhat like the eating, as well as drinking, of tea in Mongolia today where the Chinese women press tea leaves into solid blocks for export by camel caravan to the interior of Mongolia. This Brick tea is an important staple in the Mongolian diet, and is stewed in water until softened and then eaten with butter or with tsamba which is ground and parched wheat or barley. Today the U. S. is a Black tea (fermented type) drinking nation, consuming annually 68,000,000 pounds of Black tea, compared with 20,000,000 pounds of Green (unfermented) tea and only 6,000,000 pounds of Oolong (semi-fermented) tea for which the leaves are only withered and oxidized slightly before they are panned (steamed) to stop the fermentation process.

Cultivation and Harvesting. Tea is derived from the leaves of *Thea sinensis* (L.) Sims (= *Camellia sinensis* (L.) O. Ktze.), and only the bud and the first two young leaves at the end of each twig are really desirable, although the third and even the fourth leaves are used in inferior qualities. This is in sharp contrast with deliberate preference for the fully mature leaves in the harvesting of yerba maté, the popular native tea in South America.

Tea trees are grown from seed, but commercial plants are kept pruned to bush size for convenience in harvesting. Some are allowed to grow to their full natural height of 15 to 20 feet and to bear fruit, thus serving as seed trees. Seedlings remain in the nursery for a year, and after having been planted out, a first plucking occurs which is a light picking and nonprofitable. The first commercially advantageous "flushing" (complete picking) is at the end of five

years. The plants are pruned slightly annually, then drastically during the early Spring of the third year and finally collar-pruned (cut almost to the ground) when ten years old. This results in

FIG. 4. The flowers, terminal leaves and bud on a twig of a tea bush. (*Courtesy The New York Botanical Garden.*)

suckers growing up from below ground to produce a very large tea bush with several main stems. Such a plant yields a tea crop approximately every 40 days for years in a good growing area. The world's largest tea "bush" is 24 feet in diameter and 67 feet in circumference. It is on the Battawatte Tea Estates in Ceylon.

The native pickers cleverly pluck the terminal bud and the first two leaves of all the twigs on a bush, tossing them over their shoulder into a basket. If the third leaf is tender and desirable, the plucker breaks it off at the same time. The basket hangs by a strap around the head, and if a baby is brought along, the child is supported by the shoulder strap so that both of the mother's hands are free for picking.

In Japan white jasmine flowers, called "Mokle", are added to the pickings to flavor the tea and gives us the commercial "Jasmine Tea".

Processing. After plucking, tea leaves for Black tea (fermented) are spread on withering racks (chungs) for 12 hours to allow the proper degree of oxidation. They are then rolled by hand or machine to break the cells without tearing the leaves. Further oxidizing and desired fermentation are allowed until the leaves assume a copper color when spread out on tile or cement floors or tables. Firing (drying) is accomplished in baskets over charcoal fires or in tea-firing machines in modern factories. The largest tea factory in the world is on the east coast of Sumatra at Balimbingan. Leaves for Green tea (unfermented) are panned (steamed) soon after plucking to stop fermentation. In Ceylon and India freshly plucked leaves are steamed in revolving perforated cylinders. In China, Japan and Formosa, where hand manufacture is more common, the leaves are tossed about by hand in an iron vessel built into a charcoal stove. As soon as they become soft, they are removed steaming hot and rolled by hand on a bamboo mat or a paper tray. Leaves are returned to the

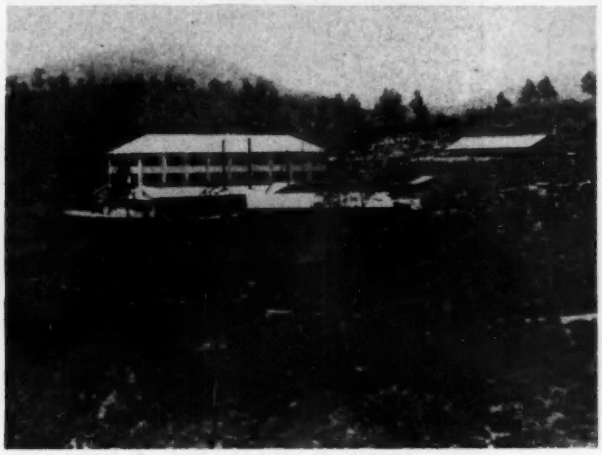


FIG. 5 (*Upper left*). Withering racks, or "chungs", for the manufacture of Black tea in Assam. FIG. 6 (*Upper right*). Ceylon tea baskets and pickers sorting out the tough third and fourth leaves from a poorly picked crop. FIG. 7 (*Center left*). Clearing the forest for tea planting. FIG. 8 (*Center right*). A tea nursery. FIG. 9 (*Lower left*). Drastic third-year pruning of tea bushes; the tall plants are unpruned tea bushes left to serve as seed trees. FIG. 10 (*Lower right*). Tea factory on a tea estate in Ceylon; the tall trees are legumes planted among the tea bushes to enrich the soil. (*Photos courtesy G. F. Mitchell.*)

FIG. 11 (*Upper*). Tea pickers of Darjeeling, India, sometimes wear shade hats to prevent premature withering of the leaves in gathering them for Green tea. FIG. 12 (*Lower*). A Ceylon tea bush as plucked or "flushed" several years for commerce, displaying many twigs from which the terminal bud and first two leaves have been picked, and which will develop new tips and be ready for plucking again in approximately 40 days. Against the card are shown a bud and the first two leaves of the twig, which are harvested every 40 days or so, as well as the third leaf which may be crushed off without injuring its axillary bud if the leaf is still tender. (*Courtesy G. F. Mitchell.*)

pan again in a few minutes, and the rolling and steaming processes are alternated until the leaves begin to crisp. They are then put into trays and dried thoroughly over slow charcoal fires.

Kinds of Tea. Harvesting the terminal buds and the adjacent two leaves together is called "fine plucking" and constitutes the finest tea. Including the third leaf is "medium plucking", and inclusion of the fourth leaf is "coarse plucking". Black tea is fermented, Green tea is unfermented, and Oolong tea is semi-fermented. "Pekoe" is Chinese for "white hair" and originally meant the earliest pickings of tea leaves covered with the young "down". "Pekoe" and "Orange Pekoe" were applied originally in China to tea scented with orange flowers. In general today, however, Orange Pekoe is a grade which results from sifting tea, after firing, through a sieve which has a mesh of a certain size. The term "Orange Pekoe" is in no sense a description of quality. The grade Pekoe is a lower leaf grade than Orange Pekoe, both of which result from sifting.

The principal kinds of Indian Tea in northern India are Assams, Darjeelings and Dooars. In Ceylon the types are High, Medium and Low-grown teas. In China the tea classification is China greens, China blacks (congous), Oolongs, scented and compressed. The three leading varieties of north China are Blacks (Keemuns, Ningchows and Ichangs), Burgundies and South China Blacks (including the Congous, red leaf Congous, Kaisows and Foochow Congous). The Clarets are Chinese. Netherland Indies teas are black teas known as "Java" and "Sumatra" together with the special identifying mark of the tea gardens in which they are grown.

Tea Tasters. Professional tea-tasters develop an amazing ability to identify the country and district of origin and

even the season of picking. Tasters sip and sip but rarely swallow. We of the United States depend upon the acuity of the specialized taste sense of less than 40 men as our guide to new fragrant blends and for the wise purchasing and blending of the leaves to maintain the uniformity of the commercial brands enjoyed by the general consumer.

Coffee

General. Coffee appeals to the human senses from its flowering stage to the aroma and flavor of the cup beverage. Its abundant and small but fragrant white blossoms, occurring in clusters and covering the small trees from six to 30 feet tall, delight the eye and perfume the air during the few days of bloom. Flowers occur once a year in dry areas but several times a year where rainfall is plentiful up to 70 inches annually. In such a climate, blossoms and green fruit, with some of the latter ripening to red and reddish black, may all occur on the tree at the same time. If the rainfall is less than 30 inches annually, irrigation is mandatory. The succulent pulp of the ripe "cherry" is sometimes eaten by the pickers. The fruit requires seven to eight months to mature and contains two seeds (beans) within the pulp, each of them possessing a parchment covering within which is the delicate but tenacious silverskin. Pulp, parchment and the silver-colored, tissue-paper-like "skin" must all be removed before roasting.

The coffee belt reaches from 20° below to 20° above the equator and extends around the world from sea level to between 5,000 and 6,000 feet elevation. Coffee flourishes best and produces the highest quality beans at about 4,500 feet, although excellent coffee is obtained at higher altitudes also, provided its great enemies, frost and drought, do not interfere. Coffee prefers a fertile soil rich in potash, and many plantations are located on volcanic hillsides and tablelands. Nursery stocks are grown from selected seeds. A coffee plant produces fruit first during its third or fourth year. Plants are pruned in the second or third year to facilitate picking and increase yield in later years. From the fifth to eighth year, when the plant reaches full maturity, to the 15th year, each tree yields one to eight, or occasionally 12, pounds of beans. The yield depends largely upon climatic conditions, and record trees have produced 17 pounds in one year. Some trees bear profitable crops up to 30 years and will produce somewhat up to 100 years. Typically, however, the trees are cut to the ground when their yield ceases to be profitable. A new tree then grows from a hardy sprout of each stock, or new nursery material is planted.

Harvesting and Processing. Climatic conditions also regulate the harvesting method. If all fruits ripen at the same time, as in relatively dry areas, they may be stripped off, but in regions where rainfall and temperature (averaging 70° F.) are more evenly distributed throughout the calendar year, the ripe fruits must be selected individually. This requires picking with greater care and over a longer harvesting period. The weather controls the time and uniformity of fruit maturity and so determines the picking season between May and September under the Brazilian climate. There is only one main harvesting season a year. Coffee picking must be accomplished when the cherries are ripe because they soon become shrivelled. Everyone—men, women and children—all take part in the harvest.

Tossing coffee cherries into the air removes more of the leaves and sticks than does sifting. After freshly picked fruits have been freed from debris, by either sifting or winnowing, they are "cured" by the dry or wet method, depending primarily upon the availability

of water. Wet-prepared, *i.e.*, washed coffees, are preferred by the market, but, because of scarcity of water during the picking season, the dry method is practiced with most Brazilian coffee and in the drier areas of other countries.

In the dry method, the "cherries", as the bean-containing fruits are known, are sun-dried in thin layers on flats, usually concrete areas, where they are raked over several times a day for three weeks. The dried fruits are then depulped and hulled (parchment removed), and the silverskin rubbed off, all in one general process by threshing or pounding in mortars on small plantations, or by special machines on the large fazendas. The machine which accomplishes removal of all three layers in one friction in a depulping machine. The slimy beans are next fermented in tanks to remove adhering traces of the saccharine pulp which is then washed away in vats. The value of this fermentation factor, which is greater in the wet method, is debatable regarding its effect upon the quality of the cup beverage.

In the wet method the "cherries" are soaked overnight in large tanks and conveyed in water to mills where the pulp is removed readily the next morning by process during this dry treatment is a different type from the depulping (only) machine used in the wet method. The beans are then graded or sized automatically by machine and bagged for warehouse storage.

FIG. 13. Coffee exhibit arranged by the author at the Sixth International Congress of Genetics at Cornell University in 1932.

As a result of this preliminary wet

method treatment the depulped "washed" coffees are clean, parchment-enclosed beans. They are next spread on concrete drying grounds for ten days with roof-like coverings on wheels to protect them against rain or the daily dew and to complete the final stages of the drying process under shade. Drying by hot-air driers in buildings gives better control and reduces the entire drying process to 24 hours. After drying, the desiccated thin parchment is peeled off and the silverskin polished off in one friction process by passing the beans between a revolving cylinder and an outer wire mesh with air blasting to eliminate dust and bits of silverskin. Grading or sizing of the cleaned beans is then performed by machine sorters; and finally, faulty and discolored beans are removed by hand. Coffee beans are packed in 60 kilogram (132 lbs.) bags for storage in warehouses, and the Serviço Téchnico of Rio de Janeiro lists eight grades for Brazilian coffee: No. 1 allows no imperfections per pound; No. 2 allows four imperfections; No. 3 allows 12; No. 4 allows 26; No. 5 allows 46; No. 6 allows 86; No. 7 allows 160; No. 8 allows 360. They are all generally referred to as either "Santos" or "Rio", according to the general area of production and port of shipment. The best Santos is known to the trade as "Bourbon". Most Colombian coffee is washed, and the finest type is grown in the Medellin region and known commercially as the "Medellins".

Unroasted coffee of the trade is known as "green" coffee. Trade classification involves not only imperfections in general but the specific physical appearance of the bean such as size, form, texture, color; and chemical characteristics of the beverage such as astringency, bitterness, dryness, harshness, mellowness, mildness, neutrality, acidity, pungency and rank. The beverage is described as being "strictly soft" (very mild and sweet), "soft" (mild and sweet), "hard" (harsh) or "Rio" (harsh and bitter). The two main trade categories are "Brazils" (strong and pungent) and "Milds" (mostly from other countries than Brazil). The best coffees for beverage utilization are blends. Green coffee has no palatable flavor. Heating to 300° F. begins to cause chemical changes. At 350° F. the beans turn yellow and aroma

FIG. 14 (*Left*). Winnowing freshly picked coffee in Brazil to remove leaves, sticks and other debris. FIG. 15 (*Right*). A Brazilian girl eating freshly picked coffee "cherries". (*Courtesy Brazilian Government Trade Bureau, N.Y.C.*)

begins. At 375 to 400° F. the brown color appears and the beans crackle due to the rupturing of the seed structure. Exact temperatures, roasting time and blending are trade secrets. The U. S. population prefers a medium roast obtained in approximately 15 minutes or somewhat longer. Commercial roasting at 1,000° F. by passing hot gases through beans in a perforated, revolving cylinder, creates an aroma and flavor by developing an aromatic oil, caffeol. This oil is highly volatile and the bean deteriorates from the moment it is roasted. For a period of a few days the rate of deterioration is relatively rapid, then much slower over a longer period. Very stale coffee is unpalatable and has changed chemically which does not improve its physiological effects. Roasting not only develops the aroma and chief flavoring compounds in the bean but it caramelizes its sugar, carbonizes its cellulose and lignin, reduces its weight 20% and increases its volume 30%.

FIG. 16. Vertical section of a coffee fruit or "cherry", twice natural size, showing the location of the deep crimson skin surrounding a yellowish pulp within which, invested first by a delicate "silver skin" and then by a cartilaginous "parchment", are the two coffee beans, or seeds.

Species. Coffee is derived from about 40 species of the genus *Coffea* L., but cultivated coffee is obtained largely from only three species, *viz.*, *C. arabica* L., *C. liberica* Bull. and *C. robusta* Linden. Within and between these species there are varieties and hybrids which, along with many other details of botanical, chemical, economic, social, literary and historical aspects, can not be discussed here because of limited space. Amplification of these phases is to be found in two volumes on the subject, one by the present author under the title "Coffee", the other by Wm. Ukers and known as "All About Coffee".

Economics. No other household beverage has had more opposition to its use than coffee, despite which it today enjoys the most wide-spread popularity of all beverages. It has been substituted for, and adulterated with, the products of other plants from 38 families involving 98 genera and 213 species. Tulip bulb "coffee" sold in Holland during World War II for $35.00 a pound on the black market, but those unhappy days are over and pure coffee is again available there. On the U. S. market, with the exception of labelled cereal substitutes, all coffee is pure coffee. A small percentage of chicory root is added in some localities, especially in the South, as preferred by public taste rather than as an adulterant. However, it was estimated in 1938 that in the world-at-large, especially in parts of Europe and including the U. S. cereal coffees named above, the quantity of imitation and adulterated coffee still drunk annually was equivalent to 10,000,000 bags of 60 kilos each.

A century and a quarter ago coffee was imported as a luxury. Today it is our pleasing and stimulating national drink. Pound for pound, tea contains more caffeine, but the coffee cup beverage has two to three times the caffeine content of a cup of tea. Our American soldiers in 1942 drank 6,000,000 cups a day, and U. S. consumption in 1946 was 2½ billion pounds—an all time record. Coffee leads the import parade of food products in tonnage (140 million tons annually) and is followed in order by sugar, fruits, fish, chocolate, tea, fancy vegetables, spices and cheese. Brazil supplies one-half the coffee demand of

the world, and the U. S. takes one-half of Brazil's production. Up to 1914 Europe was the largest market for Brazilian coffee, but since then the U. S. is Brazil's best customer. A potent factor in our "good neighbor" policy with Latin-American countries is the coffee bean because so much of their prosperity depends upon the average American's desire and ability to consume nearly 550 cups a year.

World Production. Coffee is actually cultivated in 90 geo-political areas of the world, involving 31 countries of the Americas, 14 in Asia, 9 in Oceania (Melanesia, Australia, Micronesia, Polinesia) and 36 in Africa. Production quantities give coffee a place of major importance in the economy of 40 of these countries. Of the 5⅓ billion coffee trees under cultivation in the world in 1943, over four billion were in South America and covered 8,658,076 acres. Of these four billion, Brazil had 2,790,302,700 distributed in 14 States, of which 1,482,183,300 were on the 70,000 coffee estates in São Paulo.

The world distribution of coffee trees geographically in 1943 was:

South America	4,030,640,700	trees
Central America	364,718,000	"
North America (Mexico)	133,606,000	"
West Indies	259,735,000	"
Africa	205,600,000	"
Asia	40,000,000	"
Oceania	292,500,000	"
World Total	5,326,799,700	trees

In spite of its great popularity, conditions arose a few years ago which resulted in over-production. This caused the elimination by incineration in Brazil of 77,070,577 bags of 60 kilos (132 lbs.) each, during the 12-year period of 1931–1943. The most drastic years were in 1933 when over 13½ million bags were burned and in 1937 when the total reached over 17 million bags. World production has decreased steadily since 1936, and together with control methods and the development of new uses for the by-products of coffee, such as the plastic, Cafelite, it is hoped that over-production will cease to be a major problem.

Although Ethiopia and Arabia, Africa and India are the original homelands of the coffee species, the major cultivation today is in South America. The following table indicates the geographic source of our U. S. coffee imports as shown by statistics for the years 1940 and 1945. The total in 1940 was 2,055,050,138 lbs.

FIG. 17. A coffee tree bearing fruit in the greenhouse of The New York Botanical Garden. (*Courtesy The New York Botanical Garden.*)

valued at $126,768,444, and in 1945 it reached 2,716,479,896 lbs. valued at $345,749,262. Green beans were imported from 28 different geographic areas, and a small quantity of roasted beans from a few non-producing countries such as Canada, Italy and Portugal, bringing the total to 31 sources of coffee importation into the U. S.

Chocolate and Cocoa

General. Chocolate, the most nutritious of all beverages, originated from

UNITED STATES COFFEE IMPORTS

Source	Year 1940 Pounds Raw or Green*		Year 1945 Pounds Raw or Green†
Aden, Arabia	333,011		220
Belgian Congo	6,813,585		677,278
Brazil	1,099,141,968		1,547,321,616
British East Africa	4,534,836		0
Colombia	530,023,536		601,972,779
Costa Rica	16,168,331		44,648,794
Cuba	8,290,455		1,555,865
Curaçao	19,397		0
Dominican Republic	10,508,186		34,522,531
Ecuador	27,083,304		16,008,222
El Salvador	97,309,005		120,570,196
Ethiopia	93,702		0
Guatemala	80,319,349		105,282,737
Haiti	19,047,399		61,943,761
Honduras	2,241,899		5,871,995
Jamaica	108,379		0
Mexico	52,618,854		73,142,052
Netherlands Indies	13,047,763		0
Nicaragua	30,110,600		27,208,835
Other British West Indies	16,500	(Liberia)	1,120
Other Portuguese Africa	5,422,520		5,731,783
Panama Canal Zone	460,217		644,355
Panama, Republic of	32,682		0
Peru	1,294,967		4,248,162
Saudi Arabia	3,938,638	(Sudan)	2,204,607
Surinam	459,945		0
Trinidad and Tobago	39,200		1,095,500
Venezuela	45,571,830		61,827,488
Total	2,055,050,138 lbs.		2,716,479,896 lbs.
Value	$126,768,444		$345,749,262

* A total of 14,513 pounds was imported also in 1940 in the roasted or processed state from Canada (515 lbs.), Cuba (59 lbs.), Italy (2,354 lbs.), Mexico (6,735 lbs.) and Portugal (4,850 lbs.), totalling a value of $2,114.

† A total of 610,815 pounds valued at $85,706 was imported in 1945 in the roasted or processed state from Canada (11 lbs.), Brazil (500 lbs.) and the Dominican Republic (610,304 lbs.).

a tropical American plant distributed in the mountain valleys of Mexico, Central and South America. The Mexican Indians called the beverage "chocolatl" from their word "choco", meaning foam, and "atl" for water. *Theobroma Cacao* L., its scientific name, means "food for the gods". The Aztec Emperor Montezuma would drink no other beverage from the golden ceremonial goblets. Columbus took cacao beans back to Spain, the first European country to use them. The beverage became popular only after addition of vanilla, which is also native to Mexico, became customary. There has never been a substitute for the cacao bean which gives us the liquid chocolate, cocoa which is chocolate powder with the fat mostly removed, and cocoa butter used in pharmaceutical and toilet preparations and in the manufacture of candy, beverages and foods.

The stimulating agent theobromine in cacao beans is related chemically to caffeine into which it is converted in considerable quantities by methylation. Factories have been built at São Paulo for that purpose. Unlike tea and coffee, chocolate is a real food; but like them, drinking the beverage has been a custom

for centuries and has served as a symbol of welcome and often has other social implications. The common use of chocolate at Latin-American wedding receptions originated in early Honduran Indian ceremonials. A young man would send a girl a gift of enough cacao for a celebration, and if the offering was accepted, a party followed. Then if he was in favor, the girl presented him with cacao for two parties, one to be held at his home and the other in the home of her relatives. To ask a young person bluntly in some Latin-American countries today—"When are you serving chocolate?"—implies the question—"When are you to be married?"

Cacao beans were first brought into the United States for the manufacture of chocolate by Gloucester fishermen who accepted them as money for goods exchanged in tropical America. The original mill in 1765 was in Dorchester, Massachusetts. By 1790 over 500,000 pounds were imported annually into the U. S.; in 1900 the amount brought in reached 20,000,000 pounds; today it is about 680,000,000 pounds, and chocolate is the No. 1 flavor of the country.

The Plant. The cacao plant attains a height of 40 feet in its native state as it grows in the Amazon basin of Brazil, the Orinoco river area of Venezuela and the coastal valleys of Central America. For cultivation it is kept pruned to 15 to 25 feet. It bears large red and green, glossy leaves, and its small, inconspicuous flowers and large fruits grow in a very unusual manner, appearing along the main trunk and large branches. The fruits have leathery, semi-woody rinds, and resemble small, elongated melons in size, passing through several color changes as they ripen. In matur-

FIG. 18 (*Left*). Criollo type of cacao pod, the best for flavor. FIG. 19 (*Center*). Forestero type of cacao, the source of most commercial cocoa. FIG. 20 (*Right*). Calabacillo type of cacao, the poorest in flavor but fairly resistant to the pod disease. (*Courtesy La Hacienda.*)

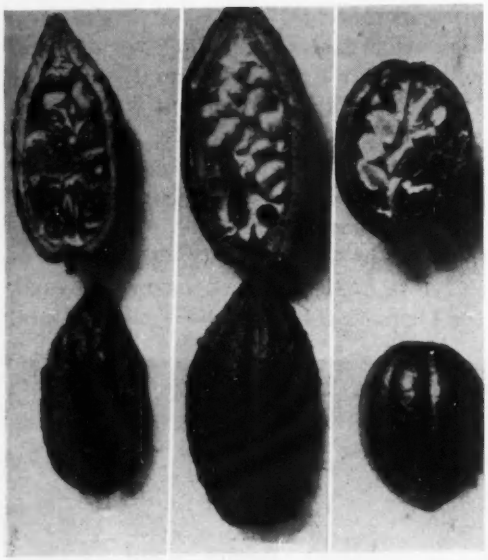


FIG. 21. Longitudinal cross-section and surface views of the three types of cacao pod; Criollo, left; Forestero, center; Calabacillo, right. (*Courtesy Pan American Union.*)

ing, the red variety turns carmine to vermilion to orange or reddish-brown, whereas the yellow variety changes from green to yellow. The impression gained by looking through a cacao plantation of mixed varieties has been likened to the effect of trees hung with Chinese lanterns. The fruits require four months to ripen, and each contains 20 to 50 almond-shaped seeds or beans embedded in a soft pulp. Each seed is enclosed in a parchment shell containing two oil lobes.

Cultivation. As is true also of tea and coffee, the quality of cacao beans depends not only on the variety but also upon the properties of the soil and climate; and upon the care exercised in controlling the curing and processing treatment. Cacao plants require a rich but well-drained soil and are so sensitive to drought and altitude that they seldom grow above 2,500 feet. They are always cultivated for the first two to four years under the shade of other trees such as banana, breadfruit, mango or rubber. Irregular rainfalls are responsible for oscillations in the volume of crops. The seeds are selected from high-yielding trees and are sometimes grown in bamboo joints or in palm leaf baskets until transferred, basket and all, to the plantation field. The tree produces fruit naturally in three years, but under cultivation, flower buds are destroyed until the fifth year. Full productivity occurs by the eighth year, and the trees continue to bear for 30 to 80 years.

With the continuous growing conditions of the tropics, flowers and pods may occur on the trees at all seasons, but there are usually two periods when many ripen at one time. This time varies in the different producing countries, but the heaviest arrivals on the world markets are in October and February. Smaller shipments are made in midsummer or early autumn.

Harvesting. Since unripe fruit gives

FIG. 22. A young cacao plant growing in the shade of large banana trees. (*Courtesy The New York Botanical Garden.*)

cacao of inferior quality and hinders fermentation changes, careful picking of mature fruit only is essential. There is an interesting division of labor between men and women during the harvest. First, skilled male pickers (tumbadores), trained in judging ripeness by the outer appearance, cut the fruit from the tree by means of mitten-shaped knives at the end of long poles. Native women fill baskets with the pods, carry them to a clearing and pile them on the ground. Opening of the multi-colored fruit is done by men who split them with a long knife by two to four blows, depending on the expertness of the laborer (peon). An expert worker can split open 500 pods an hour. Then girls separate the cacao beans from the pulp and lay them on banana leaves or trays for fermentation. Fermentation by the bean's own enzymes and by wild yeast of the air goes on for two to nine days. The wet beans are then exposed to the sun by spreading them out on concrete drying grounds for several days until dry to avoid molding, and after being graded and bagged they are stored in warehouses.

Processing. In the manufacturing process of chocolate and cocoa, the beans are "sieved" by being passed through rotating screens which remove the parchment covering (shell) and other extraneous matter. Both shells and nibs have some theobromine content. Uniform roasting of cleaned beans is accomplished in revolving drums. Crisp roasted beans are subjected to a machine which breaks them up, fans out parchment shell fragments and separates the broken beans, or nibs, into different sizes by passing them over a series of sieves. These roasted nibs contain 50% fat which is extracted and known as "cocoa butter". This butter is very useful because of its two valuable properties of freedom from rancidity and its blandness. Milling (crushing) of the nibs between grinding stones produces a thick plastic chocolate liquor which solidifies upon cooling and forms the bitter chocolate. Cocoa is the sifted powdered press cake after most of the butter (fat) has been removed from the chocolate liquor by hydraulic pressure. Cocoa possesses only 18% fat. The cacao mass to be used for various chocolate purposes is refined by additional grindings to form a smoother paste, sweetened with sugar and finally flavored with vanilla to make sweet chocolate. Powdered milk is added for milk chocolate. Extra cocoa butter is added when the chocolate is designed as a coating for bonbons. The chocolate paste is placed in a warm compartment, mixed well and deposited into the moulds of familiar commercial forms. In the manufacture of cocoa, besides reducing the fat content to 18%, sometimes sugar and dried milk are added to the sifted cocoa powder. For Dutch type cocoa the powder is treated with alkali to produce a darker color and a slightly different flavor.

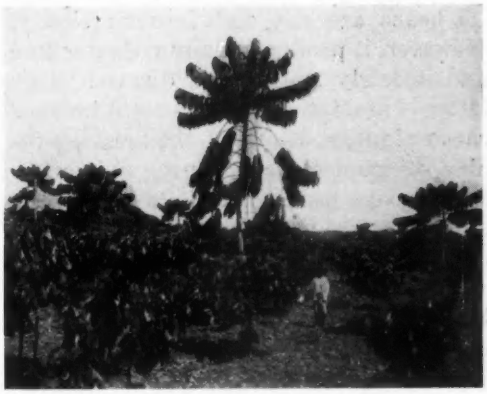


FIG. 23. Young cacao plants growing in the partial shade of castilloa trees. (*Courtesy The New York Botanical Garden.*)

Types. There are three main types of cacao, and a pure plantation of any one type is rare:

Type I. Criollo, meaning "native-born", is the finest for flavor and is

classified commercially as "fine". It is cultivated in quantity in only a few countries, and Venezuela grows much of it. Nicaragua, too, is famous for it, and the Nicaraguans consider their product, cacao del pais, to be unsurpassed.

Type II. Forastero, meaning "stranger", has three subtypes. The great bulk, 80% to 85%, of the world's crop comes from this variety. It is grown in all cacao-producing regions and bears the largest fruits.

Type III. Calabacillos, meaning "little pumpkin", is the poorest quality commercially. Its pod is the shortest and its beans are flat and ferment slowly. However, it produces many pods per tree and is fairly resistant to disease. This latter characteristic is important because cacao planting is one of the most profitable of tropical agriculture, and extensive damage has been done to the Criollo and Forastero varieties by witch's broom and pod-rot disease.

Most chocolate manufactures are blends of ordinary and fine grades, according to individual trade formulas. The U. S. is the largest consumer of cacao and imports without duty over 40% of the annual world production of over 1 billion, 700 million pounds. Although the U. S. takes two-thirds of Latin-American exports, it receives over half its total supplies from Africa. Basic chocolate products manufactured in the U. S. are valued at nearly 100 million dollars a year, and in 40 years the U. S. per capita consumption has increased from one to five pounds of chocolate products annually.

Production. Though cacao is a native of tropical America, the Gold Coast of West Africa is the chief source of the bean today, accounting for 35% of the world's cacao exports. Brazil produces 17% and is increasing her quantities annually, with cocoa now ranking third in value of all Brazilian exports. Growing wild in the Upper Amazon, it was first cultivated in the State of Para in 1740. In 1836 it was introduced into the State of Baía (Bahia) which now produces 90% of the Brazilian crop, an industry that is stimulated and regulated by the Cacao Institute of Baía, founded in 1931. A warehouse with a capacity of 250,000 bags has been built at the port of Bahia. Until 1900 more than 80% of the world's cacao crop was produced in its original habitat—tropical America—but to-day the approximate percentage distribution of world production is as follows: South America's 24% together with 8% from the Caribbean area totals 32% from the Western Hemisphere; Africa supplies 66.6%, Asia 0.9% and Oceania 0.5%, totalling 68% from the Eastern Hemisphere.

In order of the volume exported, the specific geographical sources of cacao beans are the Gold Coast, 35.6%; Brazil, 17%; Nigeria, 13.1%; Ivory Coast, 7.4%; French Equatorial Africa, 4.1%; Dominican Republic, 3.1%; Trinidad and Tobago (exclusive of re-exports), 2.6%; Ecuador, 2.5%; Venezuela, 2.2%; St. Thomas and Principe, 1.7%; Costa Rica, 0.7%; and all others about 10%. The West Indies, Central America and Mexico together produce less than 10% of the world's supply, although these areas together with Ecuador, Colombia and Venezuela have long been a source of excellent quality beans. In Ecuador cacao is the chief export, and the quality of the Venezuelan crop is unsurpassed. The United Fruit Company has aided the cacao industry by planting it on disease-destroyed banana plantations in Panama and in Costa Rica. Many of the smaller producing areas have a high home consumption of the beans. For example, in Cuba 95% of the crop is used locally, and Mexico actually imports cacao, although it also exports minor quantities. The exportable surplus of the entire Caribbean area, in fact, is far below the amounts which could be produced and

sold with great advantage to the economic welfare of the region. With this fact in mind, cacao plant-breeding experiments are being conducted by the Imperial College of Agriculture in British Trinidad.

With the constantly increasing per capita consumption throughout the world, the cultivation of this economically important plant is being, and should be, extended.

Maté

General. Yerba maté or matte, sometimes called "Paraguay Tea", "St. Bartholomew's Tea", or "Jesuit's Tea", is derived from the leaves of *Ilex paraguariensis* St. Hilaire of the holly family. The stem contains only 0.73% caffeine, but the leaves possess 1.25%. It is closely related to cassine or dahoon (*I. vomitoria* Aiton) of our southeastern coastal region where the leaves of this latter species have been the source of a minor beverage known as Cassina tea or Black drink. Maté has been long known as a potential native drink, but the North American species has never gained the acceptance accorded to the South American plant, even though the U. S. government tried to popularize it in 1923 by serving Cassina tea, a carbonated soft drink, and Cassina-flavored ice-cream to 60,000 employees of the U. S. D. A. A soft drink based upon maté and natural fruit juices has just appeared as a fountain concentrate and in the bottled form on the U. S. market in 1947 under the trade name "Matey". Two companies have been organized to manufacture it. One of them, The Matey Co., Inc. of New York, is promoting its product with a $200,000 advertising campaign through the media of newspapers, point-of-sale and radio; and the other, Martay, Inc. of Kansas City, Missouri, is sponsoring its product in that area.

Ten million South Americans drink their maté daily, and quantities of it are shipped not only throughout South America but also to Europe and the United States. The plant is one of the most important botanical possessions of the temperate zone of South America. Utilized for centuries by the Guaraní Indians, it was planted first about 1600 by the Jesuit missionaries in the Guayra Province in southern Brazil, in 22 mission areas that today constitute Argentina and along the Upper Uruguay river. The beverage is prepared usually by pouring nearly boiling water over the broken leaves in a gourd and drunk when cooled sufficiently to be swallowed comfortably. It is also brewed in tea pots and served in cups in the cities of South America, and usually in this form in North America also. The gourd method is the universal one in the rural areas.

The beverage became known as "maté" or "cúya" which mean gourd, for it is from a gourd that it is drunk or sipped through a "bombilla" ("bombilha" in Brazil). The gourds are decorated, often elaborately, and the bombillas are native reeds or bulb-shaped or spoon-shaped strainers of nickel or silver.

Great quantities of cultivated maté are grown in southern Brazil, Argentina and Paraguay, while "native" or wild maté is found over a large area in the valleys of the Paraná, Paraguay and Upper Uruguay rivers. Soil composition and atmospheric conditions affect the flavor and quality of the beverage, the flavor being "strong" or "mild" also according to the region of growth. Most maté is collected from wild plants and is known commercially as "native" maté in contrast with the cultivated product, known as "plantation" maté, produced on a smaller scale in Paraguay and in Brazil, chiefly in the States of Rio Grande do Sul, Paraná and Mato Grosso. Twenty-five acres of wild maté growth yields 2 to 4½ tons (2000 to 4,500 kilograms) of crude maté.

In the cultivation of "plantation"

maté, the young trees are pruned annually up to the third or fourth year to maintain a proper form and height of 10 to 20 feet. Harvests may be made every one, two or three years. Full productivity is reached in about ten years, and the average life of a tree of good yield is about 20 years if kept well pruned and cultivated. An average yield is about 10 kilos of dried maté per tree.

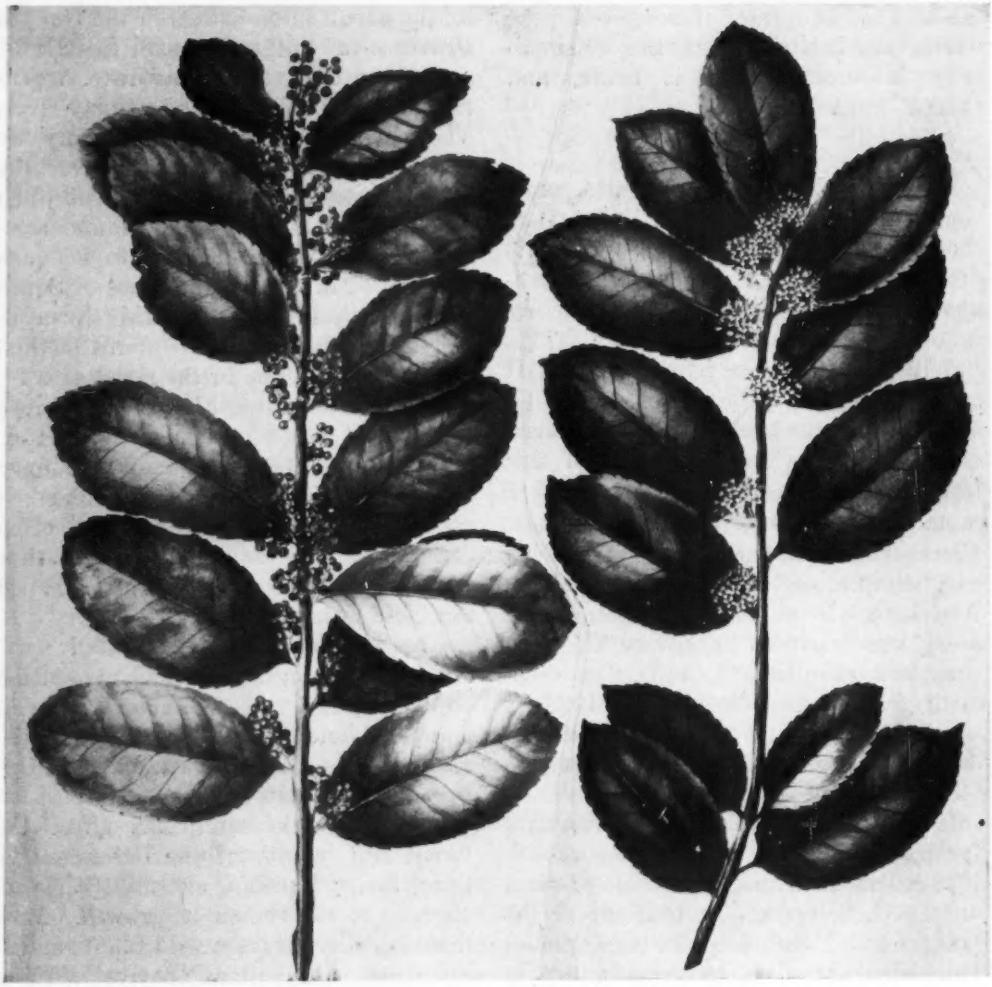


FIG. 24. Fruiting (left) and flowering (right) branches of yerba maté. (*Courtesy The New York Botanical Garden.*)

In Brazil maté is grown largely in the native state in forest areas cleared of everything but pine and Yerba Maté. In Argentina it is grown in cultivated plantations; and in Paraguay it grows wild on large tracts, though some plantations have been developed. Uruguay does not produce it on a commercial scale, but it is very popular with the Uruguayans who import over 44 million pounds annually.

Preparation. Preparation of maté involves several distinct steps which are

given an ever-increasing attention to assure a better and more uniform product. The sequence of events is cutting, toasting, breaking, drying, threshing (beating), sifting, aging and manufacturing. If carefully and properly conducted, cutting is a more elaborate process than China tea picking. The maté gatherer cleans the tree of vines, then climbs the trunk or uses a ladder and cuts off the smaller branches. A number of leaves are left at the extremities of the larger branches to provide for the breathing requirements of the tree. These tufts of leaves are known as "bandoleiras." Leaves for maté are harvested only on sunshine days between 8 A.M. and 5 P.M. when no dew or rain occurs and the leaves are not damp. Primitive Indian methods combine the toasting and drying processes by placing branches with leaves in an excavation in the ground and burning bonfires around it until the leaves are sufficiently dry to be beaten off. More recent methods utilize three separate procedures. To toast (Sapeco) leaves the operator holds the branch so that the green leaves are exposed directly to the fire for a few seconds, but turns the branch continually so that the leaves are not burned. Toasting cracks the leaves open, simultaneously reducing the moisture content 25%, and coagulates or vaporizes the gums and resins so that they do not spread through the leaves and turn them black as they do in natural wilting. The total weight of the leaves is reduced one-third.

The breaking (Quebramento) process consists of removing the short leaf-bearing branches from the larger branches, so far handled, and gathering them into sheaths for drying. Drying is accomplished by the Carijo or by the Barbacua method. The carijo is a platform of poles about six feet above ground with fires one and a half to two feet apart underneath this loose platform and carefully watched to see that the leaves on the platform are not singed. Smoke can not be entirely avoided, and this affects the taste of the beverage undesirably. The process requires 12 to 24 hours. Then the leaves are broken off. A better non-smoked product is obtained if the leaves are subjected to less smoke than it is possible to prevent in the Carijo method. The improved Barbacua method in its original form involved the Tatuape of Paraguay which consists of a low, dome-shaped, loosely formed structure of bent poles, or of bricks in modern plantations, over which the broken maté is spread, completely covering it. Hot air is conducted into this dome-like structure by a tunnel from a fire some distance away, so that smoke directly on the leaves is avoided. The leaves are turned frequently, and the process requires five to 15 hours. Threshing separates the leaves from the twigs by beating with sticks on canvas or planks spread over the ground. The resulting mass of broken leaves, bark and twigs, constitutes "maté cancheado" and can be used in this form. Modern mechanical threshing is known as "trituration". It uses a crude sort of threshing mill, operated by animal, water or steam power, and breaks off and shakes the leaves through a grate. Next, the leaves are sifted (the peneiraçao process) through a coarse sieve of bamboo and then through a fine sieve.

Ageing for a few months improves the aroma and flavor. The crude product, if handled properly, is packed dry, but not air-tight, in sacks of 30 to 60 kilograms each, and sent to the factories (engenhos or usinas). In the final manufacturing of the product, the maté cancheado is refined in factories principally at Curityba, Paraná. Since maté absorbs moisture rapidly, it is re-desiccated to protect it from molding; this additional heating, furthermore, activates the chemical constituents of the maté and thus aids in developing its flavor. It is then passed through blowers and sieves to be graded

FIG. 25 (*Upper*). Gathering leaves from cultivated seven-year-old yerba maté trees in Argentina. FIG. 26 (*Lower*). Argentinian cowboys, or gauchos, enjoying their bitter maté or cimarrón. (*Photos courtesy Pan American Union.*)

as to size. Next it is blended, since the different producing areas with their various soil, climate and curing conditions impart distinctive qualities to the maté. The milled or refined manufactured product is known as "maté beneficiamento", of which there are more than 80 brands on the market. Originally transported in raw-hide bags, the product is now packed in various containers to keep out dampness by cloth cylinders, tins or water-proofed paper and cellophane sacks.

Brewing. There are several methods of preparing the infusion for beverage purposes. "Bitter maté" ("cimarrón" or, in Brazil, "chimarrão") is brewed in a gourd without sugar. If sugar is added it makes "sweet maté", "maté dulce" or, in Brazil, "maté doce". Maté tea is made like China tea, but by using a maté containing rather large leaf fragments and by employing twice the quantity per cup that would be required for ordinary tea. Maté tea is the form used in cities and in the more patrician homes, whereas cimarrón, brewed from finely ground leaves mixed with some twig fragments, is preferred by the people of the rural districts and by the cowboys (gauchos) of the Argentina rolling plains (pampas).

Brewing is a fine art in the hands of the gaucho and other rural populations. A hollow dry gourd (maté), or sometimes a coconut shell, a cow's horn or a metal cup, is half filled with the dry ground leaves. The palm of the hand is placed over the opening, the gourd is inverted and shaken gently to mix the powdered leaves uniformly. The bombilla is inserted at an angle and a few drops of cold water added. Then nearly boiling water is added until a froth appears at the opening of the gourd. This is the real maté cimarrón, and as many as ten brews can be prepared immediately from the same leaves, although the fifth and sixth fillings have the reputation of being the best.

Caffeine Content and By-products. The physiological effect of maté is similar to that of Oriental tea, but it has an advantage possibly for people who are overstimulated by the caffeine content of tea and coffee. Maté, according to the analysis of Peckott, possesses only 2.5 grams of caffeine per 1,000 grams of prepared leaves in comparison with 4.6 grams in Black tea, 4.3 grams in Green tea and 2.6 grams in ground coffee. Maté leaves also contain only 0.01 gram of essential oil per 1,000 grams of leaves, and thus do not induce the gastric disturbance which some people experience from coffee because of the oil content rather than the caffeine in the latter. Coffee contains 0.41 gram of oil, and tea from 6.0 to 7.9 grams, compared to 0.01 gram in maté per 1,000 grams of leaves.

As a by-product, considerable purified caffeine is derived from maté, and six factories in the Brazilian States of Paraná and Santa Catarina carry out the extraction process commercially. Maté leaves also have a chlorophyll content three times that of oriental tea leaves, a quality that has made them a commercial source of chlorophyll. In 1942 one United States business concern ordered 11,000,000 pounds of Argentina maté for the extraction of its caffeine, vitamin and chlorophyll content for medicinal purposes and to make the vegetable coloring matter used extensively in food, air purifying and deodorant products, and by the cosmetic industry. One hundred pounds of crude maté yields a minimum of one pound of caffeine and five pounds of chlorophyll with a total market value of $22.50.

Consumption. The popularity of the beverage geographically among the 10,000,000 South Americans who drink maté daily may be noted by the annual per capita consumption in various areas. In Chili it is 112 lbs. and in Brazil 40 lbs., but in the Brazilian State of Paraná it is 44 lbs., even though that State exports great quantities of maté and is

also near the coffee-growing center of the world. Maté is the national drink of Paraguay where consumption is 34 lbs. per capita. Uruguay does not grow any commercially but consumes 22 lbs. per capita and imported over 44 million pounds in 1945 to meet the domestic demands. Argentina uses 20 lbs. and Bolivia 4½ lbs. per capita annually.

Grades. Since leaves from different producing areas possess different qualities, producing countries import as well as export maté in order to manufacture their desired blends. According to the quality, strength and aroma, the leaves are graded on the market as Paraguay (the best quality), Mato Grosso, Misiones, Paraná, Santa Catarina and Rio Grande do Sul (the poorest quality). Commercial grades, according to the Argentine Ministry of Agriculture, are Extra (50% Paraguay, 30% Argentina, 20% Brazil), Good (50% Argentina, 20% Paraguay, 20% Paraná, 10% Rio Grande do Sul) and Ordinary (an all Brazilian blend of 80% Rio Grande do Sul and 20% Paraná). A general industrial classification of maté for all purposes is Green, Crude and Prepared (refined for beverage consumption). Argentina imports exclusively the crude maté, whereas Uruguay and Chili import the prepared maté grade for the chimarrão form of the beverage.

Production and Consumption. Although consumption is confined largely to the producing and neighboring countries, the U. S. and Europe import maté in appreciable amounts. Brazil exports it to 16 countries. Recent total consumption figures cited in Table 1 offer a summarized statement of the present magnitude of the maté industry, based on the single plant species.

TABLE 1

Consumption Area	Pounds	Year
Argentina	259,000,000	1942
Brazil	110,000,000	1941
Uruguay	49,000,000	1936–1941 average
Uruguay	44,500,000	1944
Paraguay	12,000,000	1946
Chile	17,000,000	1936–1941 average
United States	442,149	1935
United States	82,763	1940
United States	23,909	1945

The U. S. consumption has fluctuated and decreased in recent years because of high price (70¢ to $1.00 per pound) and less advertising, and due to the fact that rapid introduction of a new beverage is difficult in a country where tea and coffee have an established popularity in the habits of the average citizen.

In 1935 Argentina set up the "Comisión Reguladora de la Producción y Comercio de la Yerba Maté" to limit, control and improve the market, and in 1938 Brazil created the "Instituto Nacional do Maté" to protect and coordinate trade in maté, and to encourage consumption. Paraguay has no similar organization but does restrict exports to assure adequate stocks for domestic consumption.

The 1943 production and export figures, according to the Pan American Union statistics, appear in Table 2.

Yerba mate is the most popular beverage in the South American geo-political areas discussed here. All immigrants, Spaniards, Portuguese, Germans, Polish and other foreign constituents of the population have learned to enjoy this beverage of the original Indian tribes and of the current civilians of long standing. Theodore Roosevelt must have thought well of its taste and effect, for he recommended maté for the U. S.

TABLE 2

	Production in Pounds	Crude Exports Pounds	Milled Exports Pounds	Total Exports Pounds
Argentina	182,981,800	.....	301,107	301,107
Brazil	158,731,200	60,800,676	45,105,508	105,906,185
Paraguay	36,305,352	13,977,004	230,758	14,207,784

soldiers in his book, "Through the Brazilian Wilderness". It certainly has the potentialities of pleasing flavor and of a desirable beneficial effect physiologically, all of which are necessary to promote it for a commercially successful world-wide beverage and to recommend it as possessing a healthful advantage to the consuming public.

Guaraná

Guaraná is the chief beverage of the State of Mato Grosso in Brazil, where 60% of all commercially produced guaraná is consumed and where it is in greater demand than coffee or maté as a daily beverage. Possessing a high tannin content (5%) as well as the highest caffeine content (5%) of any plant in the world, the beverage, so unusually rich in both these substances, serves the body as a stomachic and as an invigorating stimulant at the same time. Thus this beverage has the reputation in some parts of Brazil of being superior to coffee and tea as a healthful drink, and extravagant claims have been made for it. Guaraná, sometimes misleadingly called "Brazilian chocolate", has beverage qualities which might be described as slightly bitter, astringent and acid. It is enjoyed generally by people of all nations travelling in Brazil, and would become undoubtedly a welcome addition to the tremendous soft drink industry of the United States if Brazil could develop her agriculture and industrialization of guaraná so that she could supply the necessary volume of the guaraná paste, hard form or fluid-extract to meet the demand. The U. S. has long been a buyer of the meagre surplus available for export, and has used this limited supply mainly for medicinal treatment of neuralgia, certain cardiac conditions and intestinal disorders. The Amazon region of Bolivia is a relatively large purchaser of the paste and the bottled beverage.

The source plant is *Paullinia Cupana* H.B.K. of the Sapindaceae. It is a large, vigorous, creeping plant which produces bunches of nut-like fruits. Each round, brown seed is about the size of a hazelnut with a white, mealy covering. The plant blossoms in July, and the fruits are picked from October to December. Preparation of the hard guaraná bars, sticks or pan-cake forms is still very primitive. The ripe bunches of nuts are first soaked in water to open them. The seeds are then roasted, the seed coats removed and the seeds ground in a mortar to form a homogeneous plastic mass which is moulded into the stick form up to two inches thick and six to 12 inches long. Sometimes it is made in the form of bars or as flat pancakes weighing a half pound. The very dark reddish-brown or brownish-black stick form, the most common shape on the market, looks like a large petrified sausage. The roasted seeds are sometimes sold before grinding, and a powdered form is also known.

The native distribution of the species seems to be bounded by the southern border of the Amazon river and the area of the Madeira, Maués, and Ramos rivers. It also occurs in the Upper Orinoco and Negro river regions. Guaraná cultivation is chiefly in the State of Amazonas with a total planted area of less than 1,200 acres, mostly in the Maués district. Minor acreages are cultivated in the districts of Parintins, Itacoativa, Urucutituba, Barreirinho and Borba. Although the white population prepare their guaraná in a manner similar to that of the Indians, the Indian product from the Canumá and Maués-Acu river areas is considered to be of better quality. These Indians choose their seeds more carefully, and they make the beverage for themselves on the same day. Their modelled-stick form of the marketed product is sought as representing the highest quality.

Although guaraná has been consumed by the white population of Brazil for over a century, the production surplus for export to other white-populated lands has never exceeded 100,000 kilograms per year. The following tables convey the magnitude of the total production, export and destination figures of this beverage:

Guaraná Production

1938	155 metric tons	One metric ton is equivalent to 1,000 kilograms
1939	211 " "	
1940	172 " "	
1941	111 " "	
1942	95 " "	

Exportation from Manáos, Brazil

1935	52,205 kilograms	One kilogram is equivalent to 2.2 pounds
1936	53,354 "	
1937	30,034 "	
1938	36,072 "	
1939	99,676 "	
1940	3,816 "	
1941	2,733 "	

Exports reached their greatest quantity in 1939 when the distribution was as follows:

Poland	91,002 kilos
Germany	7,900 "
France	400 "
United States	228 "
Surinam	146 "

In 1942, for the first time, the quality of commercial guaraná was standardized. The fluid-extract is used in the manufacture of a refreshing beverage, in confections and as syrup, all three of which are enjoyed within the limited growing areas of the plant. Its very great possibilities as an ingredient of soft drinks and summer beverages have not been realized outside of Brazil.

Major Beverage Habits of the Geopolitical Areas of the World

General. A brief survey of the world's beverage plants and of their geographic production and consumption areas convinces one of the popularity of tea throughout Asia, the U. S. S. R., the United Kingdom, Canada, Australia, the Union of South Africa and other lands populated primarily by the English. The Western Hemisphere, with the exceptions of Canada (tea) and the yerba matte-drinking areas of southern Brazil, Argentina, Paraguay, Uruguay and Chile, possesses primarily a coffee-loving population with tea occupying a secondary but important place. This fact is also true of continental Europe, the Near East and most of Africa.

A glimpse at the beverage habits of various geographic regions of the world reveals also that local botanic sources are available everywhere, ranging from a few to a multitude of species and that dependence upon beverage plants ranges from the use of practically no native species, where dependence is entirely upon imported products, to areas which find satisfaction largely from native species and import very little.

Australia. In Australia, where neither tea nor coffee is grown on any substantial scale and no significant native beverage plants exist, except fruit, tea from Ceylon is the chief beverage, and the comparatively little coffee drunk is obtained from Java. The annual average for the five year period of 1935–1936—1940–1941 for tea consumption was 48,050,000 pounds and for coffee during the same period only 5,533,000 pounds. Fruit juices are consumed in great quantities and over one million gallons a year (1,044,202 gallons in 1944–1945) are exported, derived from tropical fruits grown chiefly in Queensland and New South Wales. Other fruits from these same areas and from Victoria, South Australia, Western Australia and Tasmania contribute to the total volume.

South Africa. In the Union of South Africa coffee is not produced successfully, and the amount of China tea (*Thea sinensis*) grown supplies only about 1/20 of the demand by the English-speaking population. The native

population consumes the "bush teas" derived from a half dozen wild species of the region, especially the leaves of *Athriscia phylicoides* D. C.

Canada. Canada, like the United States, has a native flora of many species which have been used for beverage purposes, but their utilization is largely historical. Canada depends greatly upon importation of tea and coffee for her non-alcoholic beverages, but fruit juices, cola and other soft drinks are common, and a small grape juice industry exists there. Apple juice and cider, too, are abundant in season, and during the summer of 1944 Nova Scotia shipped 200,000 barrels of apple juice fortified with vitamin C to Canadian and other soldiers overseas.

Iceland. In Iceland many native plants are the source of Icelandic tea, esteemed by some of the population for both flavor and vitamin content. This fact recalls the general use of rose-hip tea for its vitamin content in England during World War II because of the absence of citrus fruit juices as a major source of vitamin C in the diet. In 1945 Iceland imported 866,782 kg. of coffee, 12,557 kg. of tea, 176,627 kg. of chocolate, 23,018 kg. of cocomalt, 900 kg. of lemonade and 150,127 kg. of fruit juices, in addition to alcoholic beverages, for a population in December, 1945, of only 130,356.

Continental Europe. Denmark depends upon imports for her coffee and tea but produces much of her own alcoholic beverages, such as beer from barley and "snaps" from potatoes and corn grown primarily in Jutland.

Switzerland, in addition to an extensive viticulture for both red and white wines, devotes a considerable percentage of the apple and pear crop to the production of sweet cider and fermented cider which is consumed locally and on the rest of the Continent. Apple cider

FIG. 27. A Swiss crop of apples destined for cider manufacture. (*Courtesy Consulate General of Switzerland, New York.*)

is popular in numerous countries, and in 1945 the U. S. imported 477,007 gallons valued at $864,395, chiefly from Canada with smaller amounts from Spain and Argentina. Switzerland and Czechoslovakia have a minor commerce also in native herb teas but are entirely dependent upon imports for their China tea and coffee. Czechoslovakian vineyards are in the sheltered regions of Bohemia, Moravia and southern Slovakia. Likewise, Estonia produces fruit juices locally and imports tea, coffee and chocolate. In Russia, tea is the common beverage, and coffee is both secondary and poor in cup quality. The opposite is true in Germany where coffee leads in consumption and tea is decidedly secondary, with beer consumption high. Similarly in Italy coffee is common but in the form of a very strong brew and is drunk with milk. Tea finds only a minor usage there and wine is the major alcoholic beverage.

Turkey prepares a number of beverages from local flowers, leaves, roots and seeds, some of which are most unusual, such as the radish juice used only in southeastern regions of the country. Turkey's annual consumption of China tea is approximately 20 tons, and of coffee, 600 tons. Greece also uses a large quantity of native teas known as Greek Mountain Tea, made particularly from linden tree flowers (*Tilia vulgaris, T. alba* and *T. argentea*) and the leaves of six species of *Sideritis*. These plants, however, do not create an extensive item of commerce, since each family picks its own supply in the wild state. Coffee is consumed throughout Greece, but China tea is seen chiefly in the cities, and cocoa is rarely served outside of metropolitan areas.

In France, wine is the beverage of greatest consumption, as the average Frenchman does not usually drink water with his meals. Viticulture is a major industry, and France is the largest producer of wine in the world. Ninety-five percent of French grapes are transformed into wine or derived distilled products with an annual output of over one billion gallons. Dry wines are made from grapes of high acid and moderate sugar content; sweet wines of grapes with high sugar content and moderately low acidity. Apple and pear cider rank second in consumption, followed in descending order by beer, coffee, tea, fruit juices, soft drinks and hard liquors. Cider is produced in the northeastern area where apples thrive and pears to a lesser extent. Most of the annual cider production of 20 million hectoliters is consumed locally, but small amounts are exported in some years. All parts of France, except the North, Northwest and mountainous areas, produce wine, with the bulk of ordinary wines coming from the South of France near the Mediterranean. High quality wines come from Champagne, Bourgogue, Alsace, Bordelais and Anjou. Coffee imports average (1930–1940) approximately 480,000 metric tons and tea only 1,800 tons. The effect of World War II caused such drastic rationing that the "Ersatz" coffee in France became 90% roasted barley, acorns, soybeans and date stones. In Holland coffee became completely a black market item, and the Dutch roasted and ground their tulip bulbs as a coffee substitute. The war with its coffee rationing and unavailability of distilled alcoholic drinks resulted in a tremendous increase in the production of fruit juices in France from 15,000 hectoliters in 1935 to 300,000 hectoliters in 1943.

In contrast with France, Belgium is not a very large consumer of wine, only five liters per capita, but beer consumption there is among the highest in the world at 170 liters per year. Tea has only one ounce per capita per year, which is very low. Chocolate is also not very common in Belgium, but coffee

or coffee chicory is utilized widely. Imports of coffee in 1938 amounted to 49,000 tons, indicating an average per capita use of almost 13 pounds. Coffee chicory averages 25,000 metric tons annually or about 6½ pounds per capita. About 90% of the Belgian production of coffee chicory root is in the Province of Western Flanders. Exports of coffee chicory average 20,000 to 30,000 tons per year.

Portugal's citrus fruit juices and wines, especially port wine, are produced at home, and coffee in her colonies, but she imports all her tea and coffee for home consumption. Spain, like France, has extensive vineyards over the greater part of the country, and the per capita annual consumption of wine is 56 liters. Barley is likewise cultivated all over Spain, but beer consumption is only 2.8 liters per capita. Barley water is drunk widely and is made by maceration of toasted barley, sweetened to taste and cooled. Apple cider has a per capita use of two liters, almost as much as beer. Cider is produced mainly in the provinces of Guipúzcoa, Asturias, Navarra and Vizcaya y Alava. Fruit juices are popular and are derived from citrus fruits, grapes, red currants, raspberries and pomegranates. Among the soft drinks, sarsaparilla is common. Two unusual beverages from botanic sources are "orgeat of chufas" (Horchata de chufas), prepared from the tubers of chufa (*Cyperus esculentus*), and soybean milk (Leche de Soja) which is produced mainly in the province of Valencia. Use of the latter is beginning to spread, and the world's greatest producer and consumer of this botanical milk is Manchuria in Asia. Spain imports all her tea, chocolate and coffee.

Latin America. Nearly all the 21 countries represented in the Pan American Union produce and consume coffee, many deal in cacao, a few in yerba maté and very few in Oriental tea. There are also a number of interesting beverages derived from native plants. Some of them are to be recommended highly for much more widespread utilization. Haiti produces coffee in the mountainous regions and exports nearly 30 million bags annually. As a beverage, Haitians prefer black demi-tasse coffee or café au lait, the Haitian coffee with milk. Nearly 1⅓ million kilograms of cacao beans are exported annually which are grown in the valleys at the base of the mountains. Milk is nearly always added to the beverage form. Fruit juices are numerous in Haiti, which, in addition to those of citrus varieties, include the juices of the sour-sop (*Anona muricata*), the melon (*Citrullus vulgaris*), the granadilla (*Passiflora quadrangularis*) and pineapple (*Ananus sativus*), as well as coconut milk (*Cocos nucifera*); there is also a beverage prepared from the bark of mabi (*Colubrina reclinata*) as well as a considerable list of herb teas and alcoholic beverages used by the Haitian population.

Cuba, a producer of excellent coffee, also enjoys an appreciable number of fruit juices and beverages from native-grown plants. Mexico and Guatemala are producers of coffee and cacao, and their people, like all other Central Americans, are heavy coffee consumers. Guatemala is also a producer of China tea. Other drinks used in Guatemala are atole (corn flour gruel type) and aqua masa (fine corn dissolved in water with sugar added), and the natives of sugar cane regions consume a variety of intoxicating beverages derived from the cane and known as "Boj" and "Guarapo". Many other juices, fermented and unfermented, are also employed, such as those of tamarind, pineapple, custard apple and orgeat.

Bolivia, Peru and Chile all consume coffee, but a very common beverage in Bolivia and Peru is "chica". Chili also uses appreciable quantities of Yerba

Matte. Bolivia annually consumes one billion liters of chica prepared from corn and a half million liters of "pisco" from grapes. Chica has been common since the days of the Incas who consummated their feasts with chica quaffed from golden goblets. El Salvador is primarily a coffee-producing and consuming country. Colombia is credited with growing on the highlands the bulk of the finest mild coffee. Venezuela, in addition to its coffee grown largely in the States of Táchira, Trujillo, Lara and Mérida, also produces cacao, especially in the States of Miranda and Sucre. Tea is not produced and its import and consumption volume are not significant. Chocolate consumption is only one gram per capita per year. Everybody drinks coffee. The chief imported caffeine-containing beverages are Coca-Cola and Pepsi-Cola. Great quantities of drinks made with soda water and originating from natural gaseous water are consumed under the name of "Sodas" and "Granadinas".

The most common native beverage in Ecuador is "naranjilla". It has been selected in its fresh state by the Ecuadoreans from among all beverages as excelling for its delicate flavor and exquisite taste. The principal reason for its popularity being limited to Ecuador is the fact that pasteurization or other preservative processes tend to destroy its fragrance and color. In 1939, however, one Ecuadorean firm succeeded in sending 1,500 gallons of naranjilla juice to

FIG. 28 (*Left*). Harvesting naranjilla fruit, *Solanum quitoense*, the basis of a popular beverage in Ecuador. FIG. 29 (*Right*). Mature naranjilla fruits with their soft white hairs. (*Photos courtesy U. S. Dept. Agr., Bur. For. Agr. Rel.*)

the World's Fair in New York, and at that time a few of us Americans had the privilege of enjoying its delicious flavor and refreshment. It was accepted enthusiastically, and with the conquering of the transportation problem it will undoubtedly become a very popular fruit juice. Botanically, naranjilla is derived from *Solanum quitoense* Lam. of the family which has given the world the tomato, potato, tobacco and the eggplant. The native name "naranjilla" means

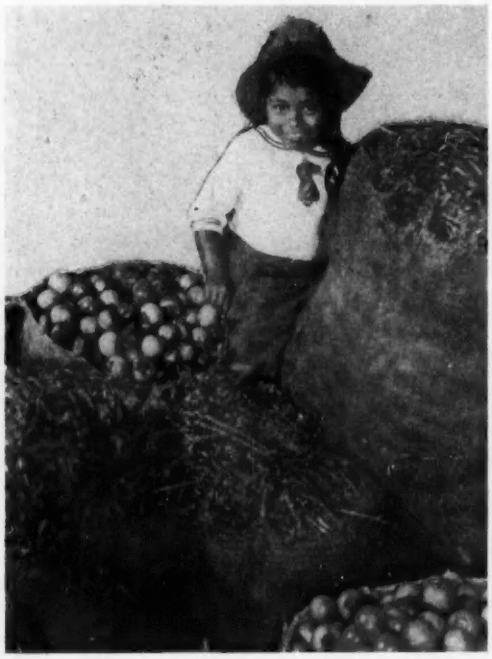


FIG. 30. Bags of naranjilla fruit ready for market. (*Courtesy U. S. Dept. Agr., Bur. For. Agr. Rel.*)

"little orange", but it would have been more appropriately called "tomatilla" because it resembles the tomato more than the orange, except for its golden color. The plant is a bush, six or eight feet tall, with large leaves sometimes 16 to 18 inches long with dark green upper surfaces and light green lower surfaces with scattered violet spots. The small white flowers in corymbs develop into round, bright orange fruits, about two inches in diameter. Fruits, leaves and branches are covered with a soft white fuzz that is lost during harvesting and handling. The natives on sloping hillsides of the middle altitude valleys of the rain forests harvest the naranjilla weekly the year round. The plant bears continuously with no special care other than one weeding operation each year during its three-year crop life. It bears fruit 14 months after the seedling is transplanted and continues for two years. Each acre bears 730 plants and yields from 180 to 360 bags of fruit weighing 125 lbs. each. Naranjillas tend to exhaust the soil, so that after a fruiting period on newly cleared land, the area is not good for subsequent crops, other than bananas or sugar cane, unless especially treated with fertilizer. Naranjillas are very sensitive to ecological conditions and develop best on well drained slopes at 4,000 to 7,000 feet elevation between latitudes 2° N and 5° S. This includes practically all of the Ecuadorean Andes. Ecuadoreans produce 2,000 tons of the fruit annually, two-thirds of which are grown in the Bãnos region of southern Ecuador. Guayaquil is the largest consumer and is the region where most of the crop is sold.

Naranjillas are consumed principally as a drink, although naranjilla marmalade is packed commercially in Quito and naranjilla pie is a choice treat among Ecuadorean hostesses. The juice is most healthful because of its content of pepsin and 1.5% proteins (albumen), with lime, phosphate and magnesium ranging from 0.98% to 1.6% of the total juice. When sugared and stirred, it makes a delicious foamy drink. It is sweet yet possesses a tartness suggestive of a combination of orange, pineapple and tomato, and has a distinctively refreshing fragrance. May Ecuadoreans find a way to successfully ship their choice beverage throughout the world.

Conclusion

Juices from home-grown fruits and soft drink consumption increased enormously in all countries, due to war re-

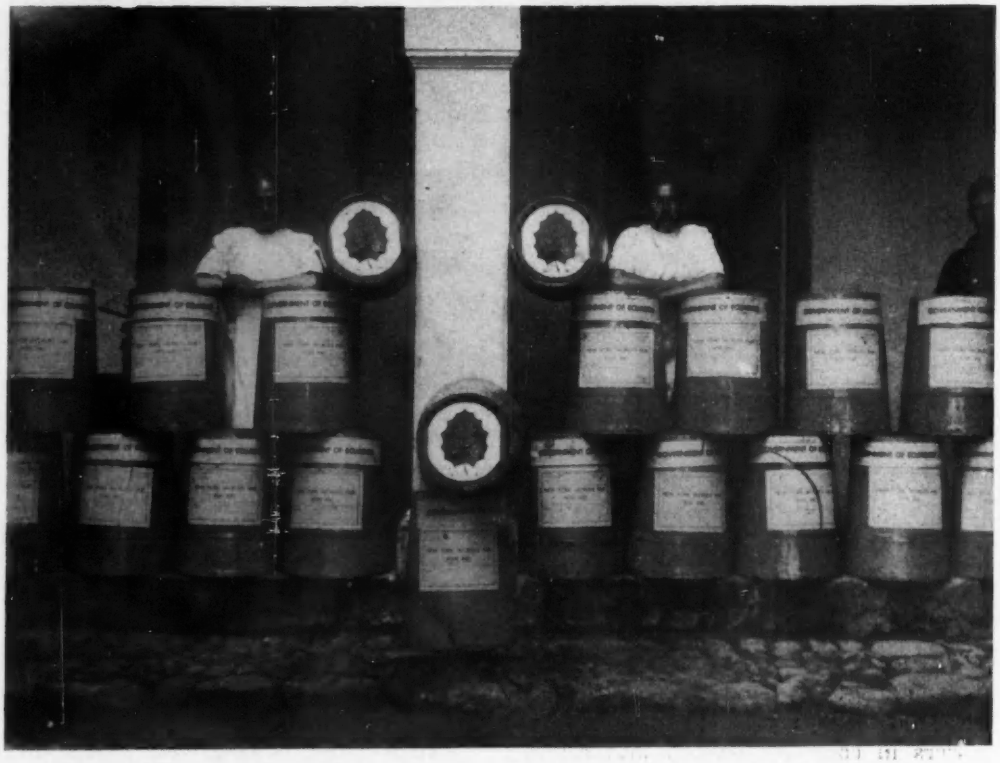


FIG. 31 (*Upper*). Naranjilla plant in flower, Province of Tunguzahua, Ecuador. FIG. 32 (*Lower*). Naranjilla juice in 13-gallon barrels for shipment to the New York World's Fair, 1939. (*Courtesy M. Chalons, Asessor Comercial y Agricola, Quito, Ecuador, and B. Oquendo, Vice-consul, Consulado General del Ecuador, New York.*)

strictions by law or by interference with importation. Because of the mineral and vitamin content and general healthful nature of such drinks, it is hoped that the consumption of these refreshing contributions from plant life will remain high on a per capita basis. The United States with her international population shows the greatest interest in the variety of fruit juices and combinations of them; also in carbonated soft drinks; but we, like all global and national areas, would do well to learn from our neighbors. We could advantageously adopt still more of the available array of beverages which would be refreshing, stimulating and healthful additions to our daily diet. This would create by their exchange, a greater utilization of native plants and an increase in employment, and thereby improve international commerce and good will between various geo-political regions. The soft drink and fruit juice industry is the beverage category in which the largest number of introductions throughout the world can be made by a global use of cola drinks, the successful shipping of naranjilla from Ecuador and a wider familiarity with yerba maté from Brazil, Argentina and Paraguay. An extension of the beverage form of the North American cranberry would also be desirable. It is a crop of 50 million pounds annually which possesses a natural tang and needs little or no fortifying. It is acidulous, pleasant and refreshing, and mixes to advantage with pineapple and orange. Its ten minerals and five vitamines make it healthful. The South American melon tree, papaya (*Carica papaya*), with its mild and satisfying flavor is finding popularity in the United States. The passion fruit which is related to our southern Maypops, has an attractive cranberry-like flavor. It was imported from Australia until the war and has been cultivated on a small scale in California. The whole fascinating question of carbonated teas, too, lies dormant on the doorstep of the beverage industry. May the re-establishment of world peace and more stabilized conditions of international commerce bring more time for the science and art of providing global enjoyment of all the best beverages. They are healthful items of the daily diet, and pleasing the sense of taste is an essential factor in good digestion and better living for everyone.

Utilization Abstracts

Soybeans. Foam fire-fighting apparatus for oil tanks, *etc.*, involves not only the reaction of carbon dioxide-producing chemicals but also an ingredient known as a "stabilizer" which prevents too rapid dissipation of the carbon dioxide through the foam. This ingredient is usually a product that possesses colloidal properties and that is derived from plant materials, the most prominent of which have been aqueous extracts of soap bark [inner bark of *Quillaja saponaria*, a tree of the Peruvian and Chilian Andes] and of licorice root [*Glycyrrhiza glabra*, an herb of Mediterranean countries]. During the exigencies of the recent war, however, particularly on ships, soybean protein [*Glycine soja*] was found to surpass soap bark and licorice for this purpose. During the war years over five million gallons of foam liquid were produced from soybeans, and in 1944 alone 900,000 bushels of the beans were thus used. This use took about 40% of the total industrial consumption of soybeans that year, and added one more to the already known more-than-one-hundred primary uses of the beans. (*J. M. Perri, Chemurgic Digest 5(12): 209. 1946*).

Taro—*With Special Reference to Its Culture and Uses in Hawaii*

A staple food since ancient times for countless Pacific island natives, taro may today be entering a new era of utilization by way of the baker's flour manufactured from it and other comestibles such as poi and paiai derived from its corm.

AMY B. H. GREENWELL
Honolulu, Hawaii

Description

TARO (*Colocasia esculenta* (L.) Schott) has been an important root crop for millions of people for well over 2,000 years. Probably originating somewhere in southern Asia, it has spread with migrating peoples to all corners of the tropical and subtropical countries of the world. It is a stemless, rank-growing aroid, conspicuous for its 18-inch to seven-foot tall tuft of petioles and pendant heart-shaped leaves which make it look like an overgrown version of its close relative, the caladium. Beneath the ground are a large fecular corm and its surrounding dormant or sprouting tubers; or, as in some varieties, an abundance of lash-like stolons devoid of tubers. The inflorescence is yellow and similar in shape to that of the skunk cabbage.

Because of their antiquity and vegetative reproduction both the genus and species are confused and extremely variable in size, shape of the corms and leaves, coloration of the leafy parts and rarity of flowers. By study of the chromosome structure this confusion will no doubt be clarified. Today there are probably about 1,000 horticultural varieties grown, each differing in some respect from the others.

Calcium Oxalate Content

Anyone who has tasted any part of an aroid is well acquainted with the prickly feeling throughout the mouth and throat a few seconds later, due to calcium oxalate crystals in the juice. Taros, as a rule, although containing a generous supply of this substance, are variable, some varieties being more acrid than others. The exact cause of this unpleasant sensation was discovered in 1836 by Turpin who saw microscopically small cigar-shaped capsules of a gelatin-like nature, open at one end, that when wetted eject crystalline spears, or raphids, into the surrounding tissues. Further study by later investigators has shown that it is this mechanical phenomenon, not the chemical action on the skin, which is irritating. They found that the surest method of eliminating this "itch" is thorough cooking, although drying lessens it considerably. Cooking breaks down the capsule, releasing the raphids, which remain unchanged, but harmless, throughout the tissues.

Old World History

Although well established as a food plant in India and Malaysia, the first known written records of taro come from China, where references are found in a dictionary and a materia medica which considered the leaves, and particularly the seeds, of value for indigestion and flatulence, and for parturient women. The plant must have arrived in Japan at an early date from either China or the

Asian mainland, as there are many varieties there very similar to the Chinese. In Japan the plant is called "imo", whereas in China it is known as "wu". Taro has always been a common staple in Japan, but is considered a delicacy in China. The first taro introduced to Sweden was brought from China in 1754 by Magnus von Lagerstroem as a hothouse curiosity and called *Arum Chinense*.

The first western records of taro are from Pliny (23–79 A.D.) who saw it growing in Egypt where it was often eaten and exported to Rome. It arrived there through Arabia where it is still called "culcas", a name that was slightly varied upon its Egyptian arrival to "qolqas". Its generic name is derived from the Greek word for the lotus with which the taro was often confused. We can be quite certain that taro was not in Egypt in ancient times, for there are not any hieroglyphics of it, as would be most likely had it been there. From Egypt, we can presume, the plant went farther west and north at later dates to Portugal and to the many Mediterranean islands where it can be found today naturalized along streams and wet places.

New World History

Taro was the important food of French Tropical Africa when slave traders were there collecting their human merchandise for the new American colonies. These men found it cheaper and easier to let the slaves subsist on their native food; hence taro, or "eddo" as the Negroes called it, found its way to the New World. It is still called "eddo" in Barbados, and to add to the confusion there is a closely related American plant, yautia (*Xanthosoma* sp.), which, along with taro, is known also as "tanya", "coco", "malanga", "oto" and by many other names, depending on the island where the plants are found. About 200 years ago another taro was introduced from China which was called "eddo de la Chine", finally contracted to "dasheen", the plant with which Americans are somewhat familiar.

It is this taro, known to commerce as the Trinidad dasheen, which was introduced by the Department of Agriculture in 1910 into the southern States as a year round crop in an attempt to find a substitute for white potatoes, that could be grown in soils too moist for the latter. The African taro and yautia had earlier found their way to these States as slave food, but, because of their coarseness, never amounted to much. The dasheen, on the other hand, has a very delicate nutty flavor, is much less fibrous and can be prepared in any way that potatoes can. However, after 36 years of attempts to encourage farmers to grow this crop, only a few do so today, as labor expenses and early frosts provide obstacles. The major problem to be faced by farmers who grow dasheens on a large scale for out-of-state markets is foreign competition. Approximately 800,000 pounds yearly are imported into the United States from the Dominican Republic, Cuba, the Azores, China and Mexico, the magnitude of exports from these countries being in the same sequence as the sources are here listed. These countries are able to grow the plant more easily and cheaply than is the United States and in spite of duties still to undersell the American market. Notwithstanding these odds, Mr. Robert A. Young of the Department of Agriculture, one of the dasheen pioneers, still hopes that the American people will at least grow the plant in home vegetable gardens, or that farmers will continue to grow it for a limited market, since the tubers are excellent for human food and the corms make good animal fodder. Blanched shoots are forced for a winter vegetable. The elephant ear, an all green plant, regarded by some authorities as identical with taro and by others as a different species (*C. antiquorum*), is sold

by some plant growers as a summer ornamental for gardens as far north as New Jersey.

Pacific History

Taro history eastward is probably more ancient and better understood than its westward spread, but the story is still far from complete. According to anthropological theories, the Polynesian people moved down the Malay Peninsula, taking with them plants which supplied food and clothing, as well as retaining methods of planting them. They traveled along the Sunda Islands to New Guinea. From Java originates the Polynesian name for the plant which we have adopted in its Tahitian form—"tales" in Java and "taro" in Tahite, "ndalo" in Fiji, "talo" in Samoa, "ta'o" in the Marquesas and "kalo" in Hawaii. According to Dr. Peter Buck, in order that the Polynesians might keep their Asiatic economic plants alive on the long journey to the central Pacific, they had to travel northwards *via* the volcanic Caroline Islands into the Gilberts, as the shorter atoll route through Melanesia was inhospitable to these plants. This theory is well illustrated by taro culture on these low islands. Holes must be dug deep down to brackish water and filled with decayed vegetable matter before a very coarse variety of taro can be grown in them.

FIG. 1. A field of dryland taro in Hawaii, in which the crowns have been set three feet apart to facilitate irrigating and weeding. When the plants are well established they are mulched and no longer weeded. (*Courtesy Hawaii Agr. Exp. Sta.*)

The first Polynesian islands to be settled were the Samoan Group, probably 2,000 years ago. From there more adventurous or harried people pushed on to the Society Islands, a fertile volcanic land, which became the base from which expeditions set out to populate the many islands to the south, east and north.

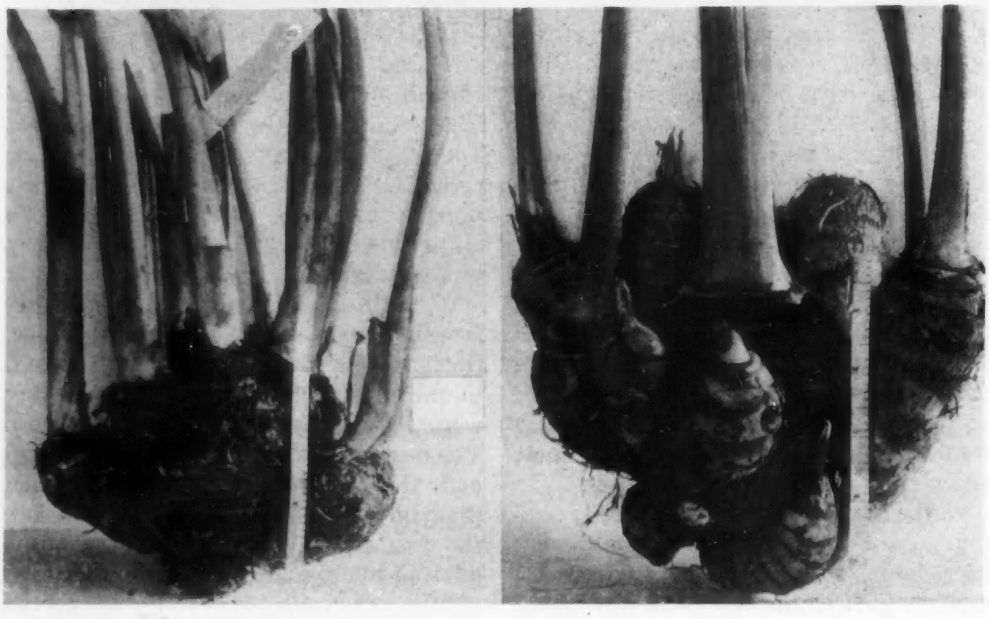
The two places which grew taro the best and where it became the staple food were Rapa, lying to the south-west of Tahite, and Hawaii, to the far north. In these relatively cooler islands many more varieties were developed, and a fermented paste was made from the steamed corms. This paste, known as "poi", is native to only these two localities.

In Rapa poi is made in a rather haphazard manner by women, as it is considered menial work for men. They bring steamed corms to large flat stones along the edge of streams and crush the taro with any handy rock. When the mass is smooth, they add a little water and knead it as we do bread dough, incorporating as much air as possible. Then the substance is allowed to ferment aerobically for a few days, thus becoming poi. It is eaten rolled into small balls on the palm of the hand, dipped into water or lemon juice and popped into the mouth.

In Hawaii taro was of such great importance to the natives that it indirectly became the basis of their civilization and social customs. The first taro to arrive in these fertile volcanic islands may have arrived with the traditional discoverer, Hawaiiloa, who landed there in 450 A.D. It was an acrid, rather coarse plant which was held in low esteem when the Hawaiians, as we know them, arrived from Tahiti around 1100 A.D. with choicer plants. Anthropologists believe that the first waves of newcomers were of the chieftain class and naturally would have brought with them the most succulent pink-cormed varieties. In time the commoners came with their supply. As Polynesian taro corms do not keep long, "huli", which consists of a quarter inch of the top corm plus about five inches of the petioles, were used for propagating because they keep for several weeks and even months if kept moist. There are theories that seeds were used in these travels, but taro seeds are rather rare and plants from them are weak.

Most of the taro was grown in water either on valley floors or on terraces built ingeniously on steep cliffs where springs were abundant. Taro was the most important food because in many sections of the Hawaiian Islands the climate is either too damp or too dry for breadfruit, coconuts and sweet potatoes to grow in profusion. Because water is of prime importance to taro culture, it had to be portioned out, and the supreme laws of the land revolved about water distribution. So that all could benefit, a great system of canals and locks was devised for all large streams which flowed into cultivated areas. Remarkable engineering feats were accomplished. Ditches were hewn in the sides of stone cliffs. Underground waterways and great stone channels were built. These, remains of which can be seen today, belie the accepted presumption that the Hawaiians were completely primitive.

Lo'i Culture. In building their wet taro patches, or "lo'i", the men of Hawaii alone did the tedious work of measuring off areas of land 10 to 60 feet square, digging down to hard soil or rock and building reinforced walls around these pits. When this was done water was let in and a day of festivity was proclaimed. Every person of rank and of all ages joined in to wade barefoot in the pond to trample the floor. Garland-bedecked, these people frolicked in the mud, and at the end of the day were feasted by the owner of the lo'i. The next day, when the mire had settled and the water was let out, the men planted the huli. Water was let in when the first leaves had expanded and was allowed to circulate constantly about the plants. The walls between the lo'i served as narrow pathways and as garden plots on which to plant sugar cane, sweet potatoes, arrowroot and other crops. When the crop was ripe, nine to 18



FIGS. 2 & 4 (*Upper and lower right*). Corms of Japanese taro, or dasheens. The abundant dormant tubers can be stored for three or four months after harvesting, and they comprise an important article of commerce in the Caribbean area. (*Courtesy of The New York Botanical Garden and of the Hawaii Agr. Exp. Sta., resp.*). FIG. 3 (*Lower left*). Corm of a Hawaiian variety, "Mana Ulaula", with its sprouting tubers. The Mana taros are peculiar for their branched corms and are held in high esteem for taro-coconut pudding. Hawaiian tubers must be eaten immediately after harvesting. (*Courtesy Hawaii Agr. Exp. Sta.*)

months later, depending on the variety, men harvested as much as was needed from time to time to make poi. The remaining was allowed to grow until needed, and the bare places replanted with huli from the harvested crop. The tops and leaves were thrown back into the lo'i as fertilizer. Often to supplement these crops fish were raised in these plats.

Dry Culture. Where running water was scarce dry land taro in Hawaii was grown either around dwellings or on upland plantations along forest borders where the soil was rich and rains frequent. Two or three huli would be placed in a hole three feet in diameter, about nine inches deep, fertilized with weeds, fern and rotted logs of kukui (*Aleurites moluccana*). From these semi-wild gardens came taro corms which weighed up to 25 pounds with no care except occasional weeding and mulching to retain moisture. The forest land was used also to plant emergency crops for times of drought or famine. Wild taros of various varieties can be seen today growing along streams or hidden away in tangled jungles.

Poi. About 150 varieties of taro were developed in Hawaii. Most of these varieties could be roasted, steamed in underground ovens, or made into poi. However, as a general rule, certain varieties were delegated to specific uses. Taro grown in dry cultivation was considered better for general eating, and taro grown in lo'i was preferred for poi, although connoisseurs considered poi from wet culture to lack richness in flavor, even to taste of stagnant water. Chiefs ate only the pink-corned varieties which now comprise the commercial taros. Most of the other varieties make grey pois, some darker than others. One variety makes a yellowish poi. All poi types are a matter of taste; therefore as the eater made the product he would select his favorite varieties, combining several of the same corm consistency, or one particular taro.

Men did all labor connected with taro, since it was considered too important for women to handle. After peeling the cooled corms, a man would sit at a long, shallowly-hollowed board or stone, and coarsely crush the taro with a heavy stone pestle. As the work progressed he used a lighter pestle, adding water to the poi until it was of the right consistency. Then he would place it in a gourd calabash and set it in a sunny place to ferment anaerobically. The amount of fermentation, too, was a matter of taste; if he wanted sour poi, three days of fermentation gave perfection. The poi was then put into smaller calabashes and mixed with water to the desired consistency, and eaten, usually with the first two fingers, although if it was thick the index finger would suffice. Some of the smaller bowls were carved with a flange on which to fastidiously wipe off the sticky paste before eating other foods. Today one hears the phrases "one-finger", "two-finger" or "three-finger" poi to describe various poi consistencies, but these terms are modernisms. "Three-finger" poi in ancient Hawaii was abhorred by everyone except gluttons who could get more poi with less effort by employing that many digits. An adult doing normal work ate ten to 20 pounds of poi per day, and, needless to say, excessive avoirdupois was the height of beauty.

Other Uses in Hawaii. Steamed pudding was made from grated taro and coconut as a sweetmeat. Petioles and leaves formed an important adjunct to meats, usually combined with coconut water. The Hawaiian feast, "luau", has taken its name from the leaves. As a delicacy the spadices were baked with fish or pork. Today all these dishes are highly esteemed by all races in Hawaii, who celebrate birthdays and weddings with luaus prepared in traditional style.

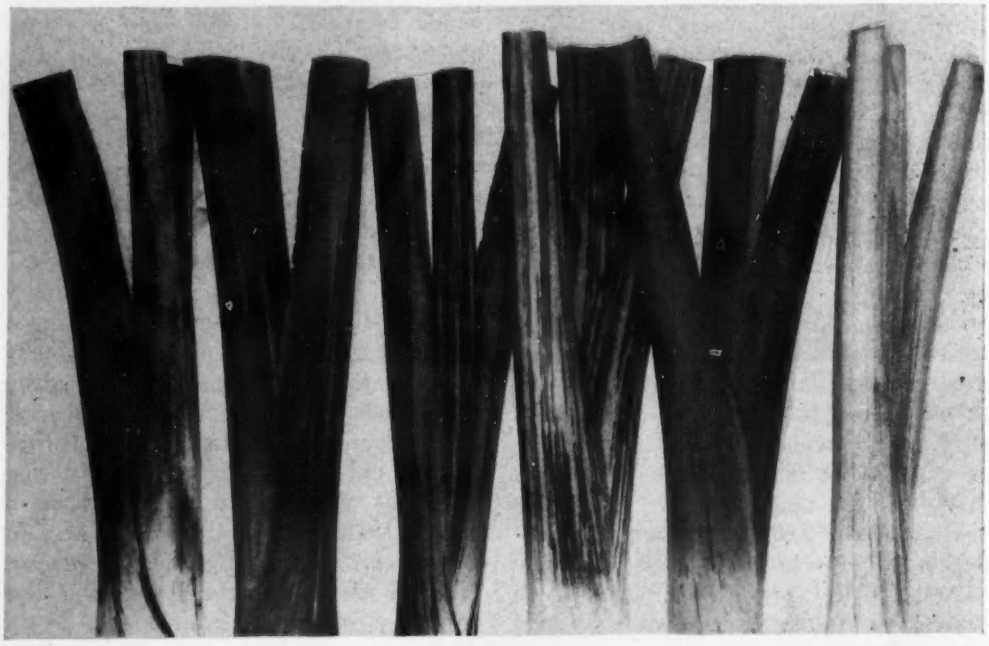


FIG. 5 (*Upper*). A nearly mature field of wetland taro. When a crop is about seven months old, just before the corms begin to mature, the water is turned off and the field fertilized; a week or two later water is allowed to enter again and to remain until the crop has matured. FIG. 6 (*Center*). Petioles of various Polynesian varieties of taro, displaying a wide range of color and much variation. There are many striped varieties in Samoa and the Dutch East Indies, as well as in Hawaii, and they offer material for very effective planting in tropical or aquatic gardens. FIG. 7 (*Lower*). Lo'i, or wet plat, prior to planting, in which huli, or crowns, are kept fresh before they are planted in rows. (*Photos courtesy Hawaii Agr. Exp. Sta.*)

Bunches of leaves and petioles are to be found at markets.

Besides being an important item of food to the natives, many taros had medical or religious significance. To understand the reasons why a particular variety had a specific use is to understand the Hawaiian system of nomenclature. Each plant has certain differences, mainly in petiole coloring, which the observant Hawaiians carefully noted. Some were speckled like a certain bird, or striped like a particular fish; others were all bright red, or purple-black; while still others were named for the fire goddess because of their smoky coloring. One taro in particular is a brilliant red petioled variety which was named for a fish of that color. This fish was frequently used for offerings; however, if the fish were unavailable the taro of the same name could be substituted.

The juice from petioles or whole leaves was used for stypties and poultices. Raw corms of mildly "itchy" varieties were grated raw and mixed with sugar cane juice for pulmonary congestion. Very thin poi was fed to infants and invalids as an easily eaten and digested food. O. W. Barret states that there is no word for indigestion in the kanaka language. This is untrue as the Hawaiians had innumerable words describing the symptoms. Poi was prescribed as a cure because the extremely small starch grain of taro and the fermented poi causes only slight irritation, if any, to sensitive alimentary tracts. Another variety was known as "ohe" or "bamboo" and was used medicinally for clysters. This taro had an extremely hard corm and was acrid, which made it unsuitable for eating, but it was often grown for the sole purpose of supplying suppositories, for which its properties were well suited. Debilitated persons were bathed in thin poi which was allowed to dry on the body, as it was supposed to improve muscle tone. Thrush was evidently a very common disease among Hawaiian children and consequently many remedies are extant. One of these is a mixture of a mild taro, raw and grated, and burnt coconut meat.

Nutritional Experiments. Today these ancient medical and religious uses for taro in Hawaii are all but forgotten except in isolated, rural communities. However, not forgotten is the fact that the old Hawaiians had extraordinarily good teeth and physiques which were built primarily by taro, eaten in conjunction with fish and seaweed. Following this presumption, Dr. Nils P. Larsen of Honolulu persuaded the Hawaiian Sugar Planters' Association to let him try a nutrition experiment with the people on one of the sugar plantations. These people were for the most part Orientals whose chief food, primarily because of racial tastes and for economy, was polished rice. Their teeth and bones were extremely poor, general health far below par, and infant mortality high, due to inferior nutrition and physical hygiene. Substituting taro for rice in the diet, Dr. Larsen proved that taro was the factor in the fine physiques of the old Hawaiians by showing the vast improvement in health of the plantation population. In 1935, as a result of Dr. Larsen's investigations, the Honolulu Sugar Planters' Association received a large grant of money from the Federal Government with which to carry out certain experiments. $50,000 of this was set aside for investigations into nutritional uses, agricultural methods and diseases of the taro plant.

Tests showed that the corm, when steamed, was a high energy food containing about 30% starch and 3% sugar. Moisture was 61%, protein a little over 1%, with a trace of fat and crude fibre. The ash produced is alkaline. When eaten in quantity, as it usually is, taro is a good source of highly assimilatable calcium and phosphorus. Other minerals

are present, but in smaller quantities. The vitamin content is similar to that in white potatoes, except for thiamin, of which taro is a greater source. The leaves and petioles when cooked are excellent sources of vitamin A and a good source of vitamin C.

The greater part of the investigation was to find out what use could be made of the corm commercially. In the past, various trials had been made to make flour. The first attempts were made in 1823 by the American missionaries who

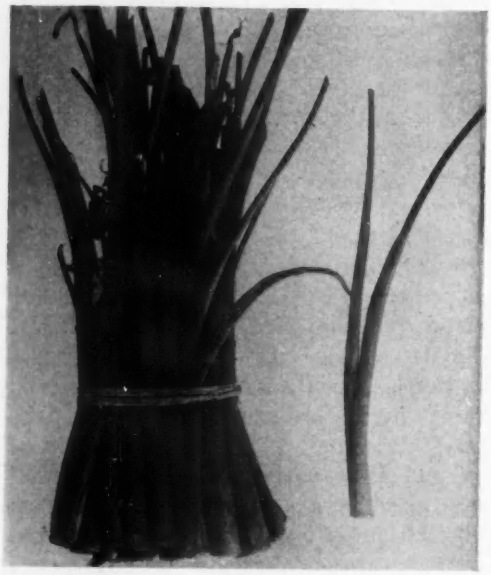


FIG. 8. Taro stalks as they are sold in Oriental markets of Hawaii. The petioles of all varieties, especially of dasheens, constitute a favorite food of the Orientals, and are diced and fried with meat or boiled as greens. (*Courtesy Hawaii Agr. Exp. Sta.*)

sun-dried raw corms and ground them in a hand mill. In 1874 scraped taro was furnace-dried. Still later in 1886 the last Hawaiian king, Kalakaua, subsidized the taro flour industry to encourage exports to other countries. By the time of the present experiments more than $66,000 was lost in attempts to produce and market taro products.

In 1935 a leader in the search for new taro uses was Gaston J. Ley. He investigated varieties of taro which would make the best flour, and sought to improve production methods in poi factories as well as to discover all possible uses for taro which would be commercially feasible. Through his work it was learned that taros which make the best poi also make the best flour. Dasheens, or Oriental taros, which do not make good poi, were found to make unsatisfactory flour. It was also discovered that pre-cooked taro is better than raw corms. Through various ways of drying cooked taro different products can be made. These can be varied by adding flavoring or skim milk either before drying or afterwards. Tray drying was found best for flour and cereals, drum drying for beverage powders. Taro corms were canned and found to be unchanged and as palatable as fresh cooked corms.

Mr. Ley decided that by using the scientific and practical discoveries made from his experiments he could successfully start a factory making these various taro products. In March of 1937, with the financial backing of several prominent Honolulu men, Hawaiian Taro Products, Ltd. was founded and went into production on an experimental basis. The initial capital was $60,000, and the capital limit $1,000,000. The factory was located in the midst of good taro-growing land, and very near transportation facilities. Flour was made in quantities of one ton daily. Beverage powders and cereals were made in smaller quantities. These products were sold both locally and in the continental United States. However, on the advent of war, the company was forced to shut down. Now under new management, this factory is beginning again, this time on a larger scale, as the products have proved their worth.

These goods consist of flour, or "Poyo-Meal", as it is called for mainland sale; "Taro-Lactin", or "Poyolin", a taro

flour-skim milk infant food; and "Taro Malt", or "Poyo-Malt", a plain or chocolate-flavored malt beverage powder. Before the war they could be found in Honolulu markets and drug stores, and on the mainland in health food stores. Now, due to extremely limited production, one must write to the company for these products.

Two more Hawaiian companies can poi mainly for local consumption, and there are numerous factories, mostly small, which produce fresh poi for local consumption.

Several other products have been tried in the past with more or less success. The most popular of these were thinly sliced pink-cormed or colored-fiber corms fried in deep fat. Both their flavor and attractiveness made these taro chips much in demand. Their manufacture was discontinued during the war, but will no doubt be revived when more taro is produced.

Two types of breakfast foods attempted by the experimental company were dry shreds and a grit which could be eaten dry or cooked. Although these were palatable they were unable to compete successfully with already established cereals. In 1888 the same fate had accompanied an attempt to make macaroni and crackers. Dried poi has constantly been tried in the islands, but has never been a commercial success.

U. S. Taro Products

In the continental United States a few attempts have been made to manufacture raw dasheen flour, also without success. At present we do not know of any company doing this work. Dasheen sprouts are forced in greenhouses in Florida as a winter crop, and when cooked like asparagus, the shoots have a flavor reminiscent of mushrooms.

Experiments have shown that taro starch has possibilities for sizing textiles, but due to a gummy substance present in all taros, commercial production might be impossible unless a cheap and easy way could be found to remove the gum.

Production Problems

Today, as in the past, many major obstacles are encountered in the Islands in producing taro and its products. The first important problem is the creation of a ready market. Because of their familiarity with the plant, Island people in all economic brackets eat taro or poi frequently in conjunction with or as a substitute for rice and potatoes. In fact, the demand for poi is so great that not enough taro is grown to supply the factories or to supply the markets with corms for table use. When corms are found they are attractively sold in the old Hawaiian type of bundle, four corms tied together with the petioles attached.

Dasheens are more common. They are peddled in vegetable wagons, or sold by the pound either whole or peeled, submerged in jars of water where they are kept until used. As dasheens are Oriental taros they are most frequently eaten by the Japanese and Chinese. In 1945, there were only 18 acres under cultivation which supplied the market fairly well. Those Orientals who have a little land invariably grow their own dasheen crop.

Taro leaves, or luau, are found occasionally at native markets, and when desired in quantities can be ordered. The cooked greens are preferred to spinach. Orientals have a preference for taro petioles, either green or blanched, and these are available solely at Oriental markets or vegetable wagons.

Medical Value

The local people of Hawaii have long been hesitant to try dried taro products, primarily because such products are different, but through the aid of local physicians the people are gradually becoming familiar with them and enjoying their

flavor. Taro-Lactin is now a regularly prescribed infant food and can be fed to a newborn baby almost immediately, according to the doctor's formula. Patients suffering from ulcers and other alimentary disorders, or convalescents, derive great benefits from this easily digested, nutritive food. It is also recommended strongly in pre-natal diets as well as for nursing mothers. Taro flour is prescribed to cereal allergy sufferers.

Flour

Taro flour is frequently used in Honolulu bakeries to make a wide variety of breadstuffs. Its properties are very similar to those of potato flour, and the flour must have the same handling; its range of possible combinations, however, is wider.

Taro bread is the most widely sold product of taro flour. Besides its distinctive color and flavor, taro bread, containing 15% taro flour and 85% wheat flour, stays fresher than ordinary bread because of the moisture-absorbing properties of taro. Cakes, cookies and doughnuts taste better when made with this flour. Because taro does not contain the glutinous properties of wheat, taro flour makes excellent thickening for gravies and puddings, as they will not become rubbery.

Experiments have shown that all varieties of taro make similar flour. Therefore, when more taro can be grown commercially, flour will probably be classified as grey, pink, yellow or white, depending on the variety, and each can be used for different food products. At present the color of taro is one of its greatest handicaps. Few foods are so variously colored. Because the most important commercial varieties are pink cormed, all dried products range from pink to salmon color. This will create one of the greater problems in educating the non-Hawaiian market to use these products.

Acreage

Once the public has become familiar with the products of taro and wishes to buy them, the farmers of Hawaii will have to plant more acreage. At the time of this writing there are only 804 acres of both wet and dry land taro grown in Hawaii, not including dasheens. Although an acre of wet taro averages 12 tons of harvested corms, and dry taro ten tons, one must remember that this crop can be harvested only once, nine to 19 months after planting, depending on the variety. The farmers, who are for the greater part Chinese and Japanese, like all farmers, want to make money. With taro land rentals excessively high and the present wholesale price of taro about $.03 per pound, the farmers would rather grow other truck crops which bring in more money per crop and which can be harvested every four months instead of every twelve.

Labor

Moreover, wet taro culture is a tedious, filthy job. With the changing social conditions among the Orientals the younger people, if they must farm, prefer cleaner work. Their predecessors came from rice-growing lands and continued to grow rice in abandoned taro patches. With the gradual decline in local rice production these lands either became pastures or reverted to taro which then had a good market. Gradually another shift is taking place to accommodate the new social change. More and more taro is being grown under dry land conditions which is similiar to other truck gardening. Before many more years go by, provided there is an increased demand for taro products, one will see wet taro only in small isolated communities.

Diseases

Another factor in the change from wet to dry culture is the higher prevalence

of disease in lo'i. The old Hawaiians spaced their taro far apart and insured a steady stream of cool water through the plot, carefully tending the plants before their roots were well established. Today, with money-making the foremost idea, the farmers crowd their plants, crop after crop, with the result that the whole field usually is wiped out by disease or by worn-out soil.

Wet taro is heir to more hazards than dry. Two rots cause the most serious damage. An unidentified Pythium rot causes the corm to become mushy and malodorous. The other is a hard rot, the cause of which is still unknown, since no definite organism has been identified. Both of these rots can be controlled by planting healthy huli from taros known to be resistant to the disease, in rotating or fallowing fields, and by insuring a circulating current of fresh water through the lo'i. Great losses are caused also by a leaf spot (*Phytophthora colocasiae*). No taro is resistant to it, but it can be controlled by planting huli 30 inches apart and by growing the plants in a cool, dryish location free from constant strong winds. Contrary to popular opinion, taro does better in a climate which has a temperature not far above or below 70 degrees Fahrenheit, and which is not too humid.

Other problems not caused by disease or poor agricultural methods are few, but have caused serious loss. Several years ago a crayfish (*Astacus nigriscens*) was introduced as frog feed, but these escaped through waterways to lo'i where they not only destroyed roots but bored holes through dykes, causing leaks. By constant treatment of the water with praradi-chloro they can be controlled. On April 1, 1946 many coastal taro fields were destroyed or damaged when a tidal wave inundated them. The lo'i were immediately repaired and the taro replaced without excessive loss.

Upland, or dryland, taro, besides being easier to cultivate, is either immune from or highly resistant to diseases common in the lo'i. A leafspot (*Phyllosticta* sp.), a root rot (*Sclerotium Rolfsii*) and nematodes cause a nuisance, but are of small economic importance. Sufficient irrigation and the above cultural precautions are used to control them. As dryland taro is usually grown at from 1,000 to 2,500 foot elevations in rich, humus soil, climate other than an insured rainfall of 70 inches is of small importance, as the temperature at these elevations is always cool during part of the day. However, with the growing importance of dryland culture for wetland varieties, the farmer must keep in mind the necessity of a cool climate.

Harvesting

Harvesting is accomplished in both wet and dry fields by hand pulling. The huli are cut off, the corms roughly washed and put into gunny sacks which hold about 100 pounds. With greater production a harvester, similar to a potato harvester, could be more profitably used, but at present hand pulling is satisfactory.

Poi

As most poi factories are situated next to the taro fields, transportation is of small importance. One exception to this is in Waipio Valley on the island of Hawaii. Waipio is one of the oldest and largest taro-growing communities and is extremely primitive. To get in and out of this deep valley one must walk or ride down a steep cobblestone road. One of the picturesque sights to see is the weekly cavalcade of pack mules loaded with large packages of paiai (dried poi) wind up the trail to the town on the brow of the cliff.

At the poi factory, usually a one- or two-room cement building, the corms are steamed under pressure as they come from the field. They are then peeled and trimmed by hand and are ground into paiai. Next, the paiai is mixed with suf-

ficient water to comply with the local pure food regulation that poi should contain at least 30% solids. It is then set aside in barrels to ferment from one to five days. Frequently a "starter" of poi is used to insure proper fermentation which is brought about by five common soil bacteria[1] that are not killed during the cooking process.

Occasionally this regulation is "complied" with by adulterating the poi with flour when taro is scarce. Other adulteration is carried out by adding pink food coloring to make common grey poi look like the choicer red poi. These practices are fortunately not often found today, although they were once quite common.

Poi is sold directly from the factory, where people queue up in long lines when it is on sale. It is sold in white cotton sacks containing about two pounds, and sells for $.20 a pound. Before the war a bag containing about five pounds sold for $.25. In rural areas a truck delivers poi to houses wanting it, where a white flag, called "poi flag", has been raised by the front gate.

Dried Products

The dried taro products factory must go through the same preliminary steps as a poi factory, except that no fermentation takes place. The paiai is refrigerated for 36 hours so that the stickiness peculiar to taro is eliminated. Chunks of refrigerated paiai are then shredded by machinery. The next step depends on the product desired. If it is to be flour or breakfast grits it is tray-dried. If it is to be beverage powder it is mixed with water and flavoring and drum-dried. "Taro Lactin" is sealed in No. 2½ tins because of the present taro shortage, but is soon to come out again in its pre-war ten-pound can. Taro flour is today sold in ten-pound tins but formerly was dispensed in 100-pound sacks for bakeries and hospitals.

At present there are only three companies which make enough poi for canning, and only one of these has a large enough supply to export. This last company, Hawaiian Foods, Ltd., formerly Hawaiian Taro Products, Ltd., is the only one making dried taro products.

The future of taro production in Hawaii is uncertain. The crux of the situation rests with the public: if they know about taro, do they want to eat more of it and its products? If they don't know about it, are they willing to give it a fair trial? The Hawaiian Foods, Ltd. is about to launch a trial balloon to find the answers to these questions. If they are successful in their endeavor, a new major industry will be developed in Hawaii and might be an impetus to California and to the southern States to seriously grow dasheens for commerce, as it has been proven that these States are well suited to its culture.

Summary

Taro roots figuratively reach back into history. Taro, in its various forms, has been grown throughout large sections of the world for more than 2,000 years. It was a familiar and important food crop in India, Malaysia, China and Japan when Pliny first saw it growing in Egypt. Egyptian taro was sent to Rome, whence it spread to Portugal and to marshes in Mediterranean islands. About 200 years ago taro even found its way from China to Sweden, where it was displayed as a hothouse curio. Negro slaves from French Tropical Africa grew taro for the first time in the earth of the New World.

While taro, in its many forms, was being carried about and cultivated in Africa, Europe and Asia, it was also putting its roots into marshes and mountain lands of countless Pacific islands. The

[1] *Lactobacillus delbrucki, L. pastorianus, L. pentoaceticus, Streptococcus lactis* and *S. kefir.*

daring Polynesian seafarers, moving across the great Pacific Ocean in double canoes, searching for and settling on new island homes, carried with them their staff of life, the taro plant. To this day taro is still the most important food in the diet of many Pacific natives.

It is worthy of mention, in summarizing the history of taro, that this interesting and healthful crop, though cultivated and eaten by millions of people throughout the centuries, has never had great commercial value. Almost without exception taro has been eaten only by those who cultivated it.

It is highly possible that today a new chapter in taro history is being written. Within the next few years taro may finally come into its own as an important commercial food crop.

Utilization Abstracts

Sesame. Since ancient times the seeds of sesame, *Sesamum indicum* of the Pedaliaceae, have been a very important source of vegetable oil in China and India. "In many parts of the world the seed is well known as an adornment on bread and rolls. To a lesser extent it is used in candy and in a refreshing drink called *horchata*. The oil, usually pale yellow when refined, is used as a salad and cooking oil and as a component in the manufacture of margarine, shortenings, and soap. Sometimes it is mixed with olive oil as an adulterant. Small quantities of sesame oil find outlets in the pharmaceutical and perfume industries. In some countries the oil is still used as an illuminant.

The leaves, when submerged in water, form a mucilage-like substance used in treatment of diarrhea and dysentery. The pressed cake makes an excellent livestock feed, containing from 10 to 20 percent oil, depending upon the method of extraction and conditions of growth".

China has long been the principal producer of the seed, and in recent years has supplied about half the world total, with India supplying about one third, and Latin America and Africa the remainer. In 1945 world production was estimated at nearly a million and a half short tons of seed, and of this quantity about 100,000 tons were grown in Latin America.

The plant, of tropical and subtropical regions, is an annual, originally from Africa, and grows two to five feet tall, producing oblong seed pods about 1½ inches long containing about 80 seeds each. The oil content of the seed varies from 45% to 55%. Harvesting begins 110 to 140 days after planting and is performed by hand cutting or machine mowing. The seeds are obtained by threshing.

Sesame is the largest single source of vegetable oil in Mexico where close to 90,000 short tons of seed were produced in 1945 and where the oil is normally used for edible purposes, secondarily in soap manufacture. In that country hydrogenated sesame oil is reported to be popular with the baking trade as a lard substitute. In Nicaragua, too, it is the most important source of vegetable oil. In the 1942–1943 season about 4,500 tons of the seed were produced there, much of it being sent to the United States. In Colombia production reached a peak of 6,800 tons of seed in 1943. In Venezuela 3,300 tons of seed were produced in 1944. Brazil, Peru, Ecuador and other countries of Latin America produce smaller amounts.

In the United States only experimental plantings have been made in the South, in California and in Arizona. During 1935–1939, previous to obtaining the seed from South America, about 27,000 short tons were annually imported, primarily from China and India. (*D. E. Farringer, Agriculture in the Americas 6: 160. 1946*).

Brazilian Timbers and Medicinals. The Brazilian Government Trade Bureau issued in 1946 the following two pamphlets of about 20 pages each: "Timber in Brazil", "Medicinal and useful plants in Brazil".

Veneers and Plywood—*Their Manufacture and Use*

Two closely related industries that depend, to a major degree, upon domestic sources of red gum, Douglas-fir, black walnut, red and white oaks, sugar maple, Sitka spruce, Ponderosa pine and Port Orford cedar; and upon foreign sources of mahogany, rosewood, zebrawood, avodiré, bossé, ebony and other exotic species.

ELLWOOD S. HARRAR[1]

Definitions and History

VENEERS are thin sheets of wood of uniform thickness produced by sawing, peeling or slicing logs, bolts and flitches. "Plywood" is a trade term applied to composite wood panels composed of an odd number of sheets of veneer bonded together with a suitable adhesive in such a manner that the grain of each adjacent layer lies at right angles to that of the next. The simplest panel is a 3-ply member consisting merely of face, core and back plies. In panels comprised of five or more layers of wood, the grain of the face, core and back plies parallel one another; the alternate sheets are known as crossbands (Fig. 1). The term "plywood" is applied commonly also to panels in which a lumber core of some predetermined thickness is used in place of the conventional veneer core. "Laminated wood" is not to be confused with "plywood", although these two terms are not infrequently used synonymously. In the restricted sense, a laminate is a multj-ply panel or structure in which the grain of all layers parallel one another.

The art of veneering is nearly as old as civilization itself and actually antedates the birth of Christ by more than 1,500 years. Exquisitely designed and skillfully fabricated pieces of plywood furniture, found in the tombs of the Pharaohs, give silent testimony to the dexterity and artistry of the ancient Egyptian cabinet makers. A number of the essential features of a modern plywood panel were found in the headboard of a bedstead reputed to have belonged to the grandparents of Tutankhamen's wife. Made of laburnum wood and lavishly embellished with gold and precious stones, it was as sound as though it were made but yesterday. How the wood was cut into thin, delicate sheets of veneers, or what was the nature of the adhesive that stood the tests of 35 centuries, is a story yet untold.

In the years that followed, Assyrian, Babylonian and Roman craftsmen, influenced by the Egyptian stylists, made several significant advances in the use of veneers in cabinetry. The Romans developed the art of matching figured veneers to produce unusual decorative effects as well as beautiful patterns of warmth and charm. In his "Natural History," Book XVI, Pliny revealed that the root-wood of certain species was often used, thus indicating that the ornamental value of stump and root-wood has long been recognized. He also recorded that among the many personal treasures of Julius Caesar, the one held

[1] Professor of Wood Technology, School of Forestry, Duke University, Durham, North Carolina.

in highest esteem was a beautifully veneered table.

During the Middle Ages and early Renaissance, oppressive ecclesiastical and political orthodoxy effectively stifled all creative thinking, cultural interests and practice of the arts. Toward the end of the latter, however, a revival for learning became manifest, and in the years that followed, some of the world's finest masterpieces in sculpture and painting were created. Interests in wood-working and marquetry were also re-born, and in 1769 Riesener completed his "Bureau du Roi" for Louis XV, said by many in authority to be the finest specimen of veneered furniture of all time. The eighteenth century also witnessed the peak in period stylings and with it the creations of such renowned craftsmen as Duncan Phyfe, Hepplewhite, Chippendale, Sheraton and the Adams brothers.

Until the middle of the nineteenth century the finest furniture was hand made, and into each piece went all the skill, ingenuity, artistry and pride of the master. Quality, not quantity, was his watchword. The work was slow, painstaking and laborious; the furniture costly and available only to the wealthy.

About 1840, furniture manufacturers began to mechanize their shops in order to produce goods on a mass production basis. In some of the shops quality was readily sacrificed for quantity. Ornate inlays and a variety of highly figured veneers were applied over poorly fabricated structure merely for the purpose of concealing shoddy workmanship. Eventually this practice adversely affected the sale of all veneered furniture because buyers began to regard such merchandise as an inferior substitute for comparable articles constructed of solid lumber. This concept is still held by many uninformed, even in these modern times, and our leading dictionaries do little to dispell this view, defining veneer as "a layer of more valuable or beautiful material over an inferior one."

Veneering as practiced today needs no defense, but rather an intelligent understanding of the purposes and advantages of veneered construction. Engineers, wood technologists, chemists and designers have combined their knowledge and skills to produce a superior wood. This is plywood. How it is made, its advantages over solid lumber, and its many uses will now be reviewed.

Manufacture of Veneers

There are at present five methods employed in the manufacture of veneers. Prior to the twentieth century, veneer logs were first cut into flitches[2], and the flitches in turn were cut into thin sheets of wood by driving them against a circular saw. This was both an expensive and wasteful procedure, since much of the best and clearest wood in a log was removed as slabs, and more than half of the potential veneer in the flitches was reduced to sawdust in the sawing operation. In more recent years rotary lathes and slicers have all but replaced the veneer saw, and today less than 5% of all veneers manufactured in the United States are sawn.

Rotary-cut Veneer. At present nearly 90% of all veneers manufactured are rotary cut. In this process a bolt of wood of predetermined length is held by two chucks and centered on a massive lathe. When in place the bolt is slowly turned against a stationary knife extending across its length. Figure 2 is a diagrammatic sketch of the modern lathe. The bolt (A), turning in a counter-clockwise direction, strikes the knife (B) and a pressure bar (C) which holds the wood firmly at the instant of cutting. The knife carriage (E) automatically moves the knife into the revolving

[2] A flitch is a longitudinal segment from a log.

bolt at a given speed, thus controlling the thickness of the sheet. The resulting veneer (D) is led out through a slot in the knife carriage. In rotary cutting, logs 12 to 16 feet in length are used by a few manufacturers. More commonly, however, logs suitable for the manufacture of veneers are sawn into peeler-bolt

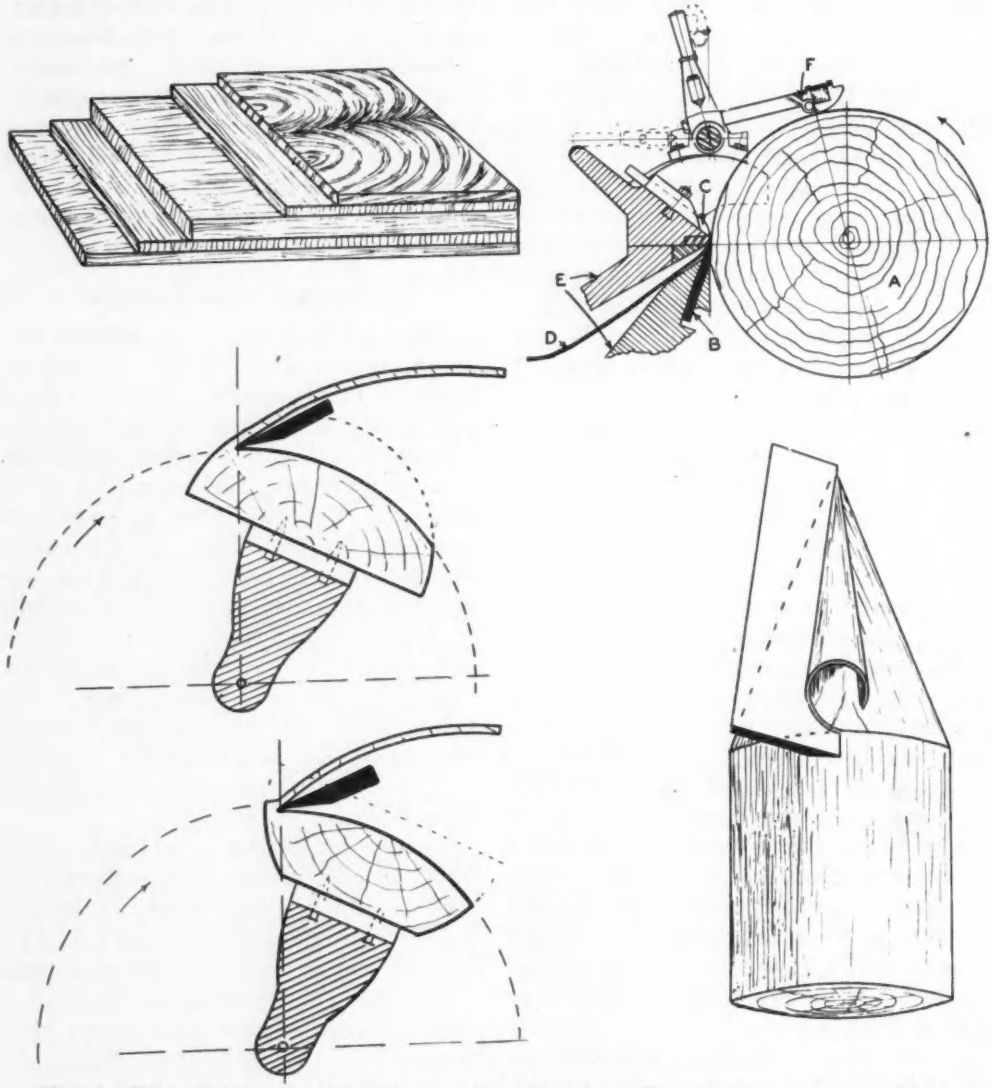


FIG. 1 (*Upper left*). Typical 5-ply panel construction. FIG. 2 (*Upper right*). Diagrammatic sketch of a modern veneer lathe. FIG. 3 (*Center left*). Diagrammatic sketch illustrating stay-log cutting. FIG. 4 (*Lower left*). Diagrammatic sketch illustrating back cutting. FIG. 5 (*Lower right*). Diagrammatic sketch illustrating cone-cutting.

a bolt is literally unwound (much as one might unroll a bolt of wrapping paper), and the veneer is produced in a long, continuous ribbon of wood (Fig. 6). Giant lathes capable of peeling whole lengths of from 24 inches to 8 feet and turned on smaller, faster lathes.

The surfaces of veneers, to be suitable for gluing, must be clean and smooth. Experience has taught the producer that

a better sheet is obtainable from woods of moderate density if the bolts are first steamed or steeped in boiling water for several hours before they are peeled. Some of the softer, low density woods, such as basswoods, yellow-poplar, Douglas-fir, spruce and cottonwood, produce better veneers if they are "cold-cut", since fuzzy, fibrous veneer surfaces are not unusual if the wood of these and similar species is subjected to preparatory heating. When bolts are heat-conditioned the bark is ordinarily removed after the cooking process.

Rotary veneers are manufactured into thicknesses ranging from 1/40 to 1/4 inch. The thicker veneers (1/8″ and up), if unrestrained, have a tendency to assume the peripheral curvature of that part of the bolt from which they are cut. When flattened the upper surface is under compression and the lower face is in tension. As a result of the tension stresses set up, numerous minute checks and cracks develop in the lower face. Veneers of this sort are said to be "one-face" veneers. The face in compression is called the "tight side", the other, the "loose side". When one-face veneers are used for face and back plies of plywood panels, the loose side is always on the glue line. In producing thinner sheets it is possible to cut them without the subsequent development of checks in the lower surface. Veneers of this sort are termed "tight-cut". Tight-cut veneers are more readily produced when excessive pressure is exerted by the pressure bar. If the pressure is intentionally relaxed, the fibers in the wood are easily ruptured and "loose-cut" veneers result. Loose-cut veneers have much less tendency to bow than do tight-cut sheets. To aid the manufacturer in keeping track of the tight side of veneers throughout subsequent operations, a scribing device on the lathe (Fig. 2, F), a pencil or crayon, marks the sheet as it is cut. This mark may be sanded out or trimmed off later in the finishing of the plywood panel.

Rotary cutting is the cheapest means of producing veneers, and the bulk of the veneers cut in this manner are of the commercial variety. Commercial veneers are those which are used largely in the fabrication of articles where strength rather than figure is of primary concern. However, the lathe is a versatile tool, and many types and grades of veneers ranging from coarse, cheap materials used for berry boxes, citrus crates and egg cases, to the expensive and highly figured face veneers of black walnut, bird's eye maple and tamo[3] used in cabinetry are rotary cut.

When a ribbon of rotary cut veneer leaves the lathe it passes over a series of table rolls which conveys it to a clipper or guillotine. Here major defects are cut out and the ribbon clipped into veneer sheets of standard widths. After sorting and grading the sheets are ready to be dried.

Stay-log Cutting. This is merely a modification of rotary cutting and is used primarily for the production of fancy face veneers cut from longwood,[4] burls, stumps and crotches.

A stay log is merely a long, flanged, steel casting mounted on eccentric chucks in a conventional lathe. A section of longwood (flitch) or other material is securely fastened to the stay log by short, heavy lag screws inserted through pre-drilled holes in the flange (Fig. 4). Longwood mounted and cut in the manner illustrated (Fig. 4) is said to be "half-round cut." Since the operator may change the radius of the swing of the stay log at will, it is possible to enhance the figure of such sheets. Stay-log cutting also permits manufacture of wider sheets of veneer than is ordinarily possible in the conventional slicing operation to be described. Fig-

[3] Japanese ash.

[4] Flitches from a log or bolt.

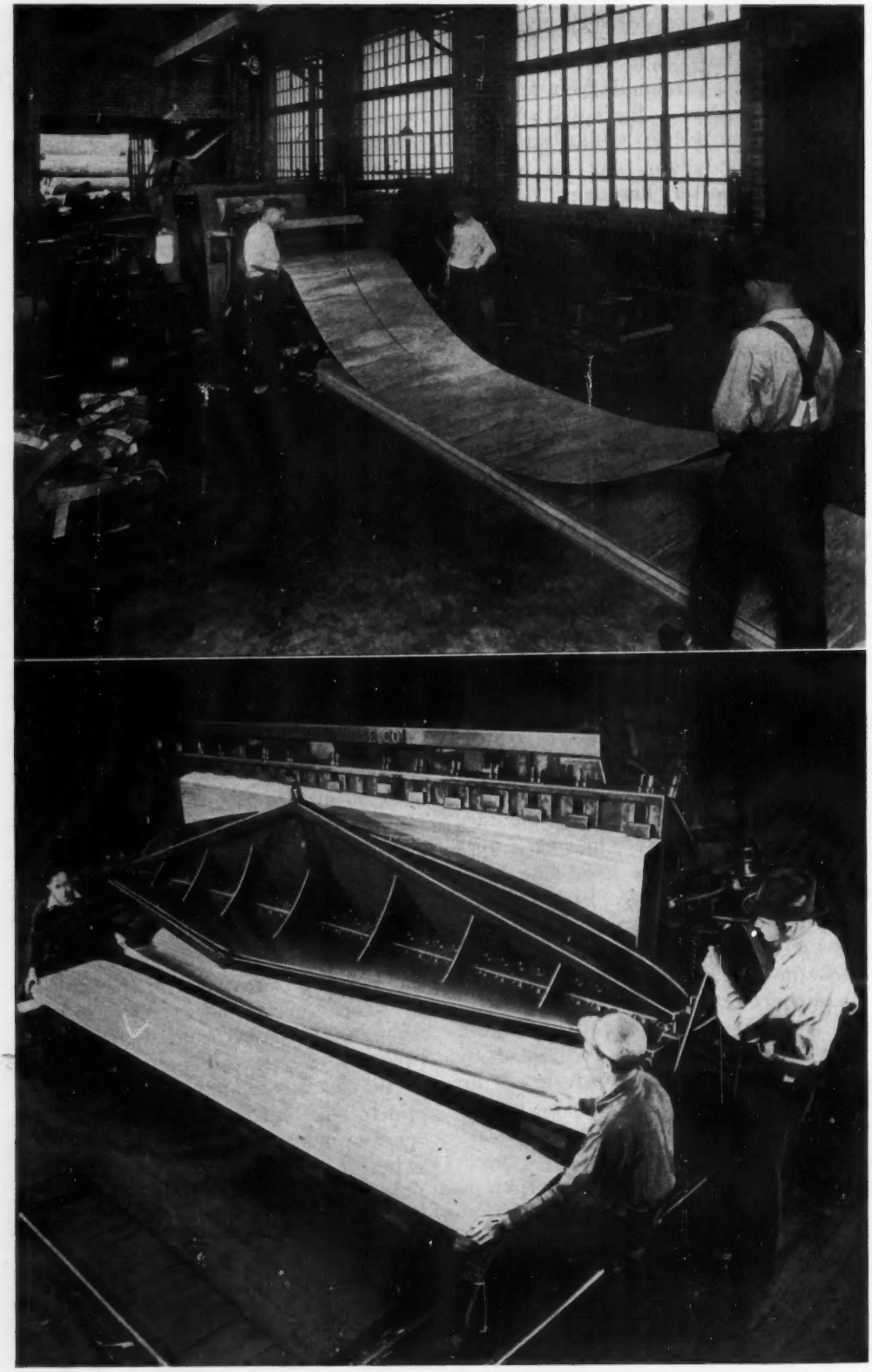


FIG. 6 (*Upper*). Rotary peeling. *Courtesy Wood Mosaic Co., Louisville, Ky.* FIG. 7 (*Lower*). Slicing a mahogany flitch. (*Courtesy Mahogany Association, Inc., Chicago.*)

ure 9 illustrates a typical "black-cut" stay-log operation. Back-cut veneers obtained from stump-wood and crotches are usually handsomely figured (Fig. 12), but care must be exercised in handling them. Fiber alignment in materials of this sort is very irregular. In consequence, much fiber is cut across rather than along the grain, and the resulting sheets are apt to be brittle, particularly when there is an abundance of "short-grain".

Cone-cutting. Cone-cut veneers are circular sheets of veneer made by taper-peeling a bolt (Fig. 5), in a manner similar to sharpening a pencil. The contact angle of the knife determines the degree of taper, the approximate width of the sheet for a bolt of given diameter, and the number of revolutions the bolt must take to produce a complete circular sheet. Veneers made in this way are "short-grained" and hence are apt to be brittle. However, they usually possess beautiful stellate or "wheel" figures and are used in the fabrication of panels for fancy circular table tops.

Sliced Veneers. Veneer slicers were developed in an effort to eliminate the wasteful practice of sawing. With numerous improvements of the original slicing device, most of the figured woods that were formerly sawn into face veneers are now cut on slicers. While slicers can be used to produce veneers of all types, they are largely used only for figured woods for face stocks.

Sliced veneers are usually cut in log lengths of from 12 to 16 feet, although cutting is by no means restricted to such limitations. Logs to be used for the production of sliced veneers are first halved lengthwise on a circular or band saw, and then not infrequently cut into smaller flitches at the option of the producer. An experienced and skilful operator is usually in charge of preparing the flitches. Upon inspection of an opened log he must be able to visualize the hidden figures it possesses, and to indicate how it is to be flitched in order that these figures may be brought out in the veneers subsequently cut. If in his judgment radial slicing is desired, the half-log is further reduced to six or eight flitches for the production of quartered-veneers, *i.e.*, the slicing plane is parallel to the wood rays and at right angles to the growth rings. If, on the other hand, "flat-cut" veneers[5] are to be sliced, no further flitching is ordinarily required. Before the actual slicing operation begins, it is necessary to tenderize the logs and flitches in steam or hot water vats in a manner similar to the treatment of bolts for rotary cutting.

A vertical slicer is most commonly used in the veneer plants of the United States. In practice a flitch is firmly "dogged" to a heavy metal bed plate fastened to two angling slides set in a heavy metal frame. The flitch is driven down against a pressure bar and knife, and the resulting sheet passes out through a slot in the knife carriage (Fig. 7), similar to that on the rotary lathe. On the up stroke the knife carriage moves forward and thus is in position to slice off another sheet with the next cutting stroke. The angling slides give the flitch a slight lateral movement as it travels toward the knife. This makes for smoother veneers, since the cutting action is somewhat along the grain of the wood rather than directly across the fibers. Such a shearing action is particularly helpful in producing smooth surfaces when woods with curly, wavy or interlocked grain are sliced.

When slicing face veneers, the sheets from a given flitch are turned over as they come from the knife and stacked consecutively, exactly in the order cut. Such a bundle is also called a "flitch", and in subsequent handlings it is re-

[5] Flat-cut veneers are made by slicing half-sections of logs. Both quarter-grained and flat-grained figures are then commonly present in the same sheet.

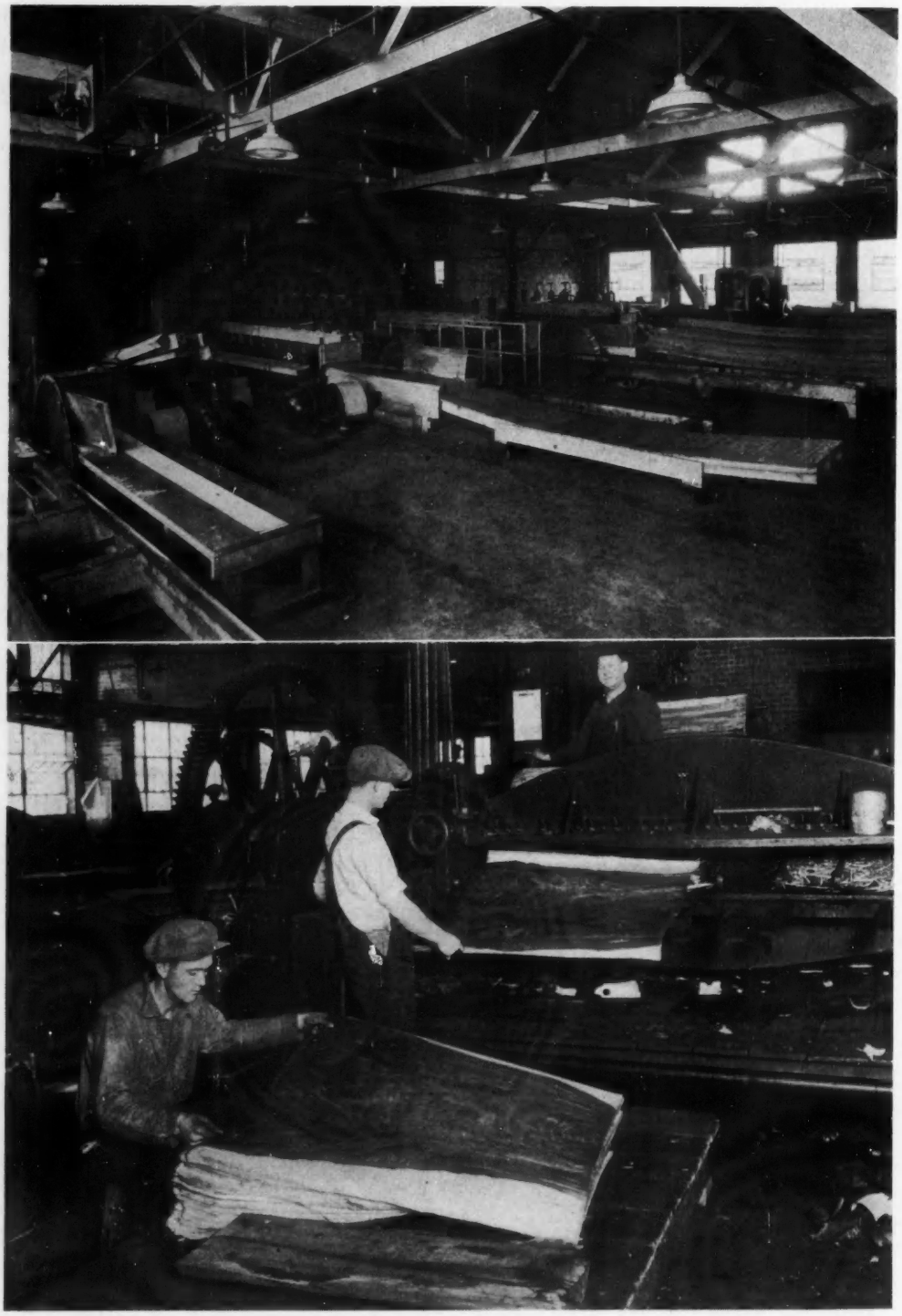


FIG. 8 (*Upper*). Battery of veneer segment saws. FIG. 9 (*Lower*). Walnut stump being cut on stay-log. (*Photos courtesy Wood Mosaic Co., Louisville, Ky.*)

garded as a unit; especial care is exercised to preserve sheet sequence at all times. The reasons for this will be explained later.

Sawn Veneers. In these modern times but little veneer is produced by sawing. Ordinarily sawing is restricted either to woods of cabinet rank that are highly refractory and unsuitable for slicing (ebony, satinwood, knotty eastern red cedar), or to those that cannot be tenderized in cooking vats without impairing their color. Woods with appreciable tannin are commonly sawn, since hot tannin extracts coming in contact with a knife impart objectionable iron tannate stains to the wood.

The modern veneer saw is known as a "segment saw" (Fig. 8). It consists of a heavy metal, tapering flange (mounted on an arbor) to which are bolted several thin, saw-steel segments along its periphery. In this way the kerf is considerably less than that of a conventional circular saw blade of similar size. Despite this, about half of a flitch is reduced to sawdust in the production of 1/20″ veneer.

Sawing a sheet of veneer differs little from the conventional method of sawing a board. A flitch, prepared in the usual manner, is fastened securely with timber dogs to a carriage and then driven into the whirling blade. When the saw has passed through the flitch, the carriage returns to its former position, moves forward a distance equal to the combined thickness of a sheet and saw blade, and the cutting operation is then repeated.

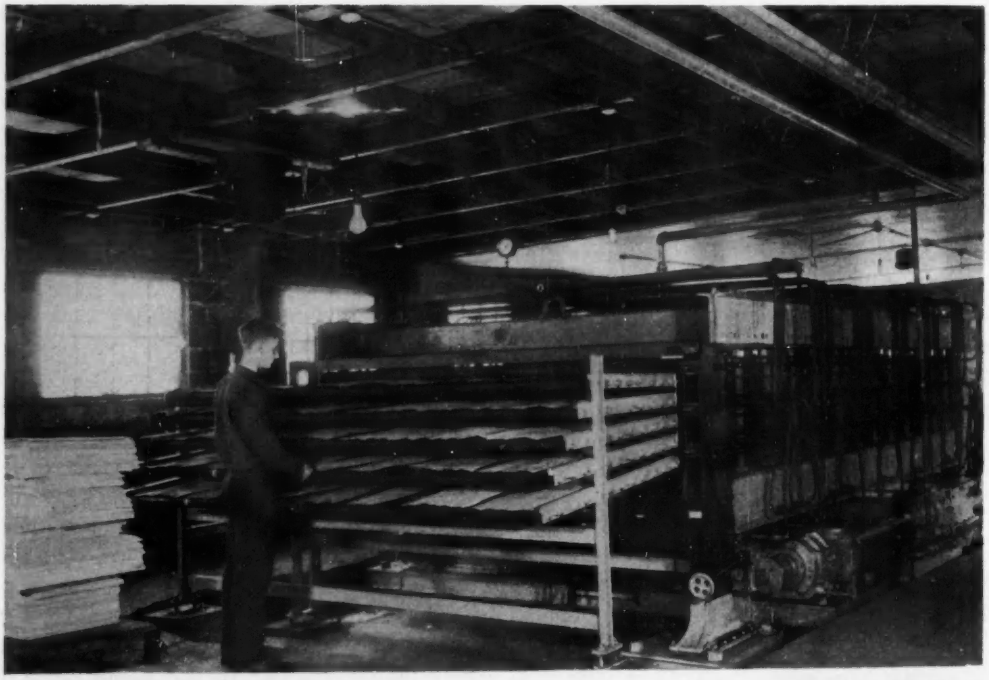
Port Orford cedar and basswood slats for venetian-blinds, and cedrela shook for the manufacture of cigar boxes are also commonly made with a segment saw.

Veneer Thicknesses. Veneers are cut in a wide variety of thicknesses, ranging from 1/110 to 3/8 of an inch. Most of the rotary veneers are 1/7″, 1/8″, 1/9″, 1/10″, 1/16″ or 1/20″ thick. Sliced veneers usually range from 1/20″ to 1/40″, but the bulk of face veneers so cut are either 1/20″ or 1/28″ in thickness. The very thin sheets of cedrela (Spanish cedar, *Cedrela odorata*), used to wrap individually fine cigars, and some other speciality veneers are often only 1/100″ to 1/110″ thick. During World War II, 1/64″ mahogany veneers were used in the manufacture of wing-skins for aircraft. Sawn veneers vary from 1/4″ to 1/32″ in thickness, with 1/20″ stock being the most common.

Veneer Drying. Freshly cut veneers are ordinarily very wet, and in that condition are wholly unsuited for gluing. Moreover, they are readily susceptible to the attack of molds, blue stain and wood-destroying fungi. Thus it is necessary that excessive moisture be removed from them as rapidly as possible, consistent, of course, with good drying practices. Exception to this general rule may be found in the basket industry. Since wood is much more pliable when it is wet, it may be bent to much sharper curvature without danger of rupture. Hence the basket weaver commonly works with wet veneers, and dries them only after the product is fabricated.

Several methods for drying veneers are in common use. The selection of one of them for any given plant is usually dependent upon the ultimate use of the stock and the facilities available to the manufacturer.

1. *Air drying.* The cheap grades of rotary (and occasionally sliced) veneers used for fruit and vegetable crates, egg cases and packing case materials are sometimes dried in the open. In such instances they are dried merely enough to prohibit the growth of fungi and to reduce shipping weight. When air drying is practiced, the sheets are laid between tiers of stickers, or loosely stacked on end in finger racks in order to permit free circulation of air over their surfaces.



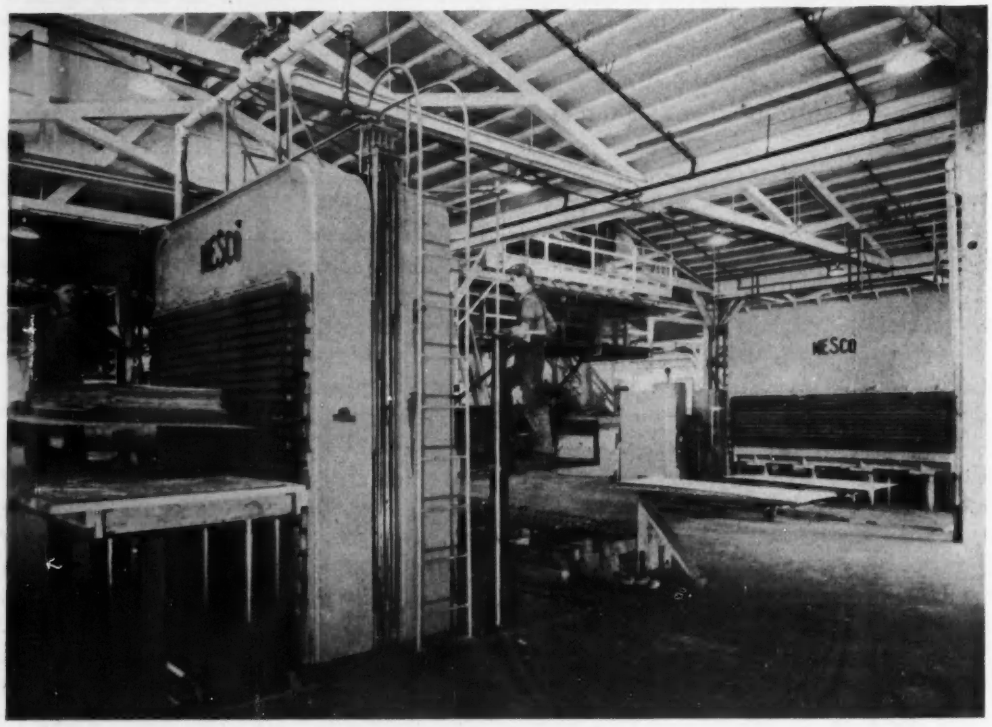


FIG. 10 (*Upper*). Roller type, five-deck conveyor drier. FIG. 11 (*Lower*). A modern plywood hot press. Wet lay-ups are fed in from the left and the bonded panel is removed from the back of the press upon completion of the bonding cycle. (*Photos courtesy Merritt Engineering & Sales Co., Inc., Lockport, N. Y.*)

2. *Loft drying.* A loft is merely a well ventilated room, with or without humidity control. Wet sheets of veneer are hung on clips from rafters or edge stacked in finger racks. Here they remain until the moisture content stabilizes at 12% to 15%. In thin sheets of the order of 1/20″ in thickness, only a day or two is required to bring the moisture content down to within these limits if suitable drying conditions prevail.

3. *Kiln drying.* The conventional, progressive type, lumber dry kiln is also used in drying veneers. In practice several sheets are bulked between each tier of stickers. One plant in North Carolina producing 1/8″ rotary red gum veneer bulks 10 sheets between stickers and dries them to a moisture content of 6% in 48 hours.

4. *Veneer driers.* At the present time most veneers are dried in carefully designed and engineered devices that permit rapid and uniform drying without adversely affecting the sheets. Two types of such equipment, namely, conveyor driers and hot-plate driers, are in common use.

Conveyor driers are chambers 50 to 100 feet or more in length, fabricated of sheet metal and suitably provided with heating equipment, and two to six paired banks of power-driven rolls or belts to move the veneers longitudinally through them (Fig. 10). The rapidity with which veneer passes through driers of this sort is dependent upon numerous variables such as original moisture content of the wood, manner in which veneers were cut, veneer thickness, degree of dryness required, and efficiency of the drier itself. Rotary cut 1/8″ sweetgum veneer may be dried to a moisture content of 4% to 6% in 13 to 16 minutes in driers of this sort.

Hot press driers consist of a bank or battery of heated platens. Sheets of veneer are placed on the upper faces of the platens that are then brought together to keep the sheets flat while drying. During the drying interval the platens are intermittently opened and closed to allow moisture to escape as it is driven from the wood. Driers of this sort are very efficient but have a smaller capacity than the conveyor type. However, when floor space is at a premium they are to be preferred.

The Veneer Industry. A large variety of woods, both foreign and domestic, are utilized in the manufacture of veneers, but more than one-half of the total annual American output is comprised of red gum and Douglas-fir (*Liquidambar styraciflua* and *Pseudotsuga taxifolia*, respectively).

Hardwood veneer manufacturers are widely scattered throughout eastern United States, although there are a few plants on the West Coast. These manufacturers are divided into three categories, according to the kind of veneer they produce.

1. *Face-veneer manufacturers.* These usually limit their activities to the production of sliced, sawn or stay-log cut fancy face veneers from carefully selected logs, burls, crotches and stumps. Such materials are usually handsomely figured and are used as facings for plywood panels employed in the fabrication of furniture, pianos, cabinetry, and for interior decorative paneling.

There are more than 50 manufacturers of face veneers scattered through the Ohio and Mississippi River valleys and adjacent territories, the Lake States and in larger cities along the Atlantic seaboard.

The manufacturer of face veneer cuts his raw materials as received and builds up sizable inventories which are stored in well ventilated warehouses. After each flitch is dried and bulked in sheet sequence it is given an identifying number. One or more samples are then removed from each flitch. A sample nor-

mally consists of three sheets, one taken from near the top of the flitch, one from about the middle and one from near the bottom. The flitch identification number is marked on these samples together with the total square footage in the flitch. These samples are sent to salesmen who sell the entire flitch based upon the samples shown. The importance of preserving sheet sequence of face stocks now becomes evident. The buyer in examining the sample sheets can determine the degree of uniformity of figure in the entire flitch, and whether it is suitable for his needs. A uniform figure is essential to the manufacturer who matches veneers to produce highly figured panels. A prospective buyer can also determine length, width and thickness of sheets, variation in color and smoothness of cut from properly selected samples of this sort. Practically all face veneers are sold in this manner.

In normal times some 80 or more kinds of face veneers were offered to the trade. Importation of exotic woods was greatly curtailed during the war, and many stocks have long since been exhausted. Several of the most popular species, however, are again beginning to appear on the market. Among the American hardwoods, black walnut (*Juglans nigra* L.) bole-wood, stump-wood, burls and crotches, quartered red and white oaks (*Quercus* spp.), sugar maple (*Acer saccharum* Marsh), quilted maple (*A. macrophyllum* Pursh) and figured red gum (*Liquidambar styraciflua* L.) have enjoyed extensive use. The more popular exotic woods were the American mahoganies (*Swietenia Mahagoni* (L.) Jacq. and *S. macrophylla* King), the African mahoganies (*Entandrophragma* spp. and *Khaya* spp.), Indian rosewood (*Dahlbergia latifolia* Roxb.), Brazilian rosewood (*Dalbergia nigra* Fr. Allem.), zebrawood (*Brachystegia* spp.), avodiré (*Turraeanthus africana* Pell.), bossé (*Guarea cedrata* Pell), Macassar ebony (*Diospyros* spp.), lacewood (*Cardwellia sublimis* F. Muell.), red lauan (*Shorea negrosensis* Fox.), orientalwood (*Endiandra Palmerstoni* C. T. White), prima vera (*Tabebuia Donnell-Smithii* Rose), tigerwood (*Lovoa Klaineana* Pierre), Ceylon satinwood (*Chlorophora swietenia*) and West Indies satinwood (*Zanthoxylum flavum* Vahl.). Prices per square foot ranged from two to thirty-five cents per square foot, depending on quality, figure, scarcity and demand.

Specially prepared, very thin face veneers reinforced with cloth or canvas backings and suitable for hanging on plaster, much in the manner of wall paper, are sold under the trade name of "Flexwood".

2. *Commercial veneer manufacturers.* Commercial veneers, or "utility" veneers, are those used for cross-bands, cores and backs of plywood panels, and for concealed parts of furniture, such as drawer bottoms, case and mirror backs, and dust sealers. These are rotary cut and are made from several species of domestic woods. Manufacturers of veneers of this sort are usually located with respect to adequate supplies of suitable timber. Beech, birch, maple and basswood veneers are produced in large quantities in Wisconsin, Michigan and New York. Red and sap gum, yellow poplar, cottonwood, tupelo, sycamore and oak veneers are made in many southeastern plants from the Ohio River region to the Atlantic and Gulf coastal plains.

Unlike the manufacturer of face veneers, commercial veneers are cut to order, species, thickness, sheet size and grade requirements being specified. A few, however, restrict their production to sheets of a standard size. Most commercial veneer is sold to furniture, piano or radio manufacturers who make their own plywood or to plywood plants that build stock panels or who manufacture

panels to customer specifications. In several instances a veneer plant is but a part of a large mill manufacturing plywood panels, in which case the entire output of veneer is consumed in the fabrication of panels within the facility.

3. *Container veneer manufacturers.* Facilities of this sort manufacture a wide variety of cheap veneers suitable for crates and packing cases, hampers, fruit and vegetable baskets, kits, meat, butter and picnic dishes, cheese boxes,

FIG. 12 (*Upper*). Two-piece match, mottle brown stripe, of Honduras mahogany. FIG. 13 (*Lower*). A modern radio cabinet constructed with veneer. (*Photos courtesy Mahogany Association, Inc., Chicago.*)

barrels, hoops and similar items. Such plants are usually established proximate to adequate supplies of cheap timber and suitable markets. When wire-stitched or stapled, and scored merchandise is made, a preference is usually shown for woods of lower density, such as cottonwood and sap gum.

Softwood veneer manufacturers are concentrated along the Pacific rim where several large and very modern plants are engaged in the production of rotary cut Douglas-fir, Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and ponderosa pine (*Pinus ponderosa* Doug. in Lawson) veneers. Substantial quantities of Port Orford cedar (*Chamaecyparis Lawsoniana* (A. Murr.) Parl.) sliced veneer are used in manufacturing storage battery separators. In the southeastern United States bald cypress (*Taxodium distichum* (L.) Rich.) and several of the southern yellow pines are used to a limited extent in the production of core and cross-band materials for use with hardwood face veneers.

More than 80% of all softwood veneers cut in the United States are made from Douglas-fir. The Douglas-fir industry has made tremendous strides during the past decade, and in the year preceding V-J Day had expanded its facilities to the point where it was capable of producing more than six billion square feet of veneer annually.

Douglas-fir veneer is almost entirely consumed in the fabrication of structural plywood panels and for interior paneling. Some container veneers are manufactured from Sitka spruce and ponderosa pine where they find a ready market in the citrus industries of California and the hard and soft fruit growers of the Pacific Northwest.

Plywood Manufacture

Of particular significance in the fabrication of a plywood panel is its balanced construction. A balanced panel is one that has an equal amount of wood in each grain direction and is symmetrical on both sides of its center line. Thus in 3-ply construction the thickness of the core is essentially equal to that of the combined thicknesses of the face and back sheets. In a 5-ply panel the combined thicknesses of the cross-band layers (Fig. 1) corresponds to the aggregate thickness of face, core and back plies. Panels composed of 7, 9 or more plies are similarly constructed. Construction of this sort provides for maximum strength and materially equalizes the strain in all directions. It also minimizes shrinking or swelling due to atmospheric changes and is thus considerably more stable than ordinary lumber. If properly constructed, warping is eliminated.

The manufacture of a plywood panel consists of (1) preparing face and back, cross-band and core sheets, (2) edge-jointing individual plies preparatory to forming large continuous sheets when required, (3) laying up and spreading the adhesive, (4) pressing the glued stock into a panel, and (5) drying and finishing the panel.

Veneers delivered to a plywood manufacturer are checked for moisture content, and, if necessary, are redried. If the sheets are not wide enough to make a panel of required dimensions, two or more sheets are spliced together to attain the necessary width. This is done by running the sheets through an edge joiner which makes a smooth straight edge. The sheets are then butted together along these dressed edges and fastened together with paper tape or a film of glue. This splicing operation is done mechanically with machines called tape splicers, or, if glue is used, tapeless splicers, and are standard equipment in nearly every plywood factory.

When figured sheets of face stock are built up in this manner, it is common practice to reverse (turn over) each

alternate sheet when an even number of them is used. In this way it is possible to form pleasing patterns of bilateral symmetry (Fig. 12). This practice is one form of matching veneers.

The next phase of panel manufacture is the gluing operation. In 3-ply panel lay-up, a dry back ply is placed on a caul.[6] If the liquid adhesive is used, the core sheet is run through a pair of rolls rotating in a bath of the adhesive, the glue spreader. These rolls are so adjusted that the thickness of spread may be regulated in accordance with the glue manufacturer's recommendations. The core in turn is placed upon the back ply, and a face sheet is then laid upon the core. This procedure is repeated until a stack of panels has been built up that will completely fill a press. The elapsed time between the initial spread of glue and the development of full pressure in the press is very important, particularly when synthetic resin adhesives are used, since a pre-cure without adequate pressure invariably results in no bond strength. Accordingly, this operation is carefully regulated in order to avoid such an eventuality.

Fabrication of 5, 7 or more ply panels is very similar. In such instances the cross-bands are usually run through the glue spreader. When double spreading is practiced, all plies are spread, the face and back sheets being run over a single glue-spreading roll.

Where cold pressing is practiced, that is, when glues are used that will cure at room temperature, wooden cauls are employed. Cold-pressing is usually time-consuming, however, since several hours or even days are required to effect a complete cure of the adhesive. Thus a plant using cold-pressing procedures must provide for ample press capacity. Cold pressing may be accomplished in screw presses, screw clamping devices, or in a variety of hydraulically operated machines.

[6] Cauls are sheets of aluminum, or plywood with oiled or waxed surfaces, used to equalize pressure and hold them flat during the pressing operation.

Hot-pressing, on the other hand, involves the use of heat to effect the cure of an adhesive. When hot pressing is employed each lay-up is placed between a pair of metal cauls. Figure 11 illustrates a modern multi-platen press used in the manufacture of hot pressed plywood. The platens are hydraulically operated and internally heated. When the press is opened a lay-up between two cauls is laid on each platen. As soon as the press is charged it is closed and full pressure built up as rapidly as possible. Presses of this sort will bond wood satisfactorily in two to 30 minutes, depending upon the thickness of stock and distance of the glue line farthest removed from the heat source, nature of the adhesive and platen temperatures employed.

In recent years the use of radio frequency heat has also been used successfully in curing plywood bonds.

After their removal from the press, panels are often permitted to recondition (moisture stabilization) and are then cut to size and finished in accordance with customer specifications. If the faces are made up of spliced sheets, the tape which is always on the outside of the panel is sanded off.

Plywood Adhesives. Adhesives suitable for bonding of plywood panels must be of such a nature that they may be spread easily and uniformly. They must not impart objectionable stains to the veneers, nor should they lose any of their bonding strength upon aging. In some instances it is essential that they be highly water-resistant.

Six classes of adhesives are currently used in panel fabrication, *viz.*, hide and animal glues, starch glues, casein glues, blood albumin glues, vegetable protein glues and synthetic resin glues. Hide glues, once the most universally used,

are now rapidly disappearing from plywood plants. Blood albumin glues have been very popular in European countries, but have had only limited use in the American industry. Starch glues first appeared on the market about 1912, while casein adhesives were an outgrowth of World War I. The vegetable protein glue, a soybean derivative, appeared on the market about 1923. The first of a series of synthetic resin adhesives made its appearance in 1935, and in the short space of a dozen years nearly the whole plywood industry has gone over to their use.

Synthetic resin adhesives are thermosetting plastics, which when cured, form hard, infusible films of great strength. At present there are two important classes of thermosetting resins available, *viz.*, the phenol-formaldehyde (including resorcinol) types, and the urea-formaldehyde (including melamine) types. Within these two general categories are many formulations, the choice of which is largely dependent upon the nature of the product being manufactured, durability of the bond, pressing equipment available and considerations of cost.

Phenol-formaldehyde resins are available in sheet form (Tego film), as a liquid, or as a dry powder that may be mixed with water, alcohol or acetone. Resins of this sort are used when hot-press plywood is made. Platen temperatures of 260° F. or more are usually required to effect total cure, although there are certain formulations available, called warm setting phenolics which may be cured at much lower temperatures. Resins of this sort form water proof, boil proof bonds, and plywood made with them is suitable for many external uses, such as hulls for small boats, aircraft and external paneling in house construction.

Resorcinol-formaldehyde resins are of the phenolic type but may be cured at room temperature. If temperatures are elevated to 150° to 200° F. cure may be effected in a matter of minutes.

Urea-formaldehyde resins are supplied in liquid or powder form. These resins will cure at room temperatures, but if heat is applied the reaction is greatly expedited. Urea resins are not as moisture-resistant as the phenolics, and if inadequate pressure is applied during the pressing interval, thick glue lines result. It is essential that the veneers bonded with urea resins be in intimate contact with one another, since thick glue lines eventually craze, and under such circumstances delamination is inevitable.

Melamine-formaldehyde resin adhesives are among the newest of the synthetic bonding agents. They possess many properties intermediate between the ureas and the phenolics.

Molded Plywood. Panels with single or double curvature, such as those used in aircraft skins, hulls of small boats, or in some of the most modern furniture designs, cannot be made with ordinary pressing equipment. Thus molding techniques, in which use is made of fluid pressures, have been devised.

In one molding process, veneers interleaved with film glue or coated with a liquid resin are laid-up upon a male mold of wood or metal and temporarily held in place with wire staples, tape, or by other suitable means. Such an assembly is then placed in a large flexible rubber bag from which the air is immediately expelled. As the vacuum is drawn the bag presses firmly against the veneers, causing them to conform to the contour of the die. The deflated bag and its contents are then placed in a large steel autoclave where steam or hot water is admitted under pressure. Adequate fluid pressure is brought to bear in this way and the heat cures the resin. At the completion of this cycle the molded item is removed and the operation repeated.

A somewhat similar process employs

the use of a female mold. In this instance veneers are laid-up along its inner face and covered with a rubber blanket attached to the die. Air is usually expelled beneath this covering so that the veneers are pressed firmly into place. This assembly is then similarly handled in the manner described above. There are a few variations of these two methods for molding panels of unusual shape and contour, all of which utilize a fluid pressure system to assure that adequate and uniform pressure is applied to the panel during the bonding cycle.

Densified Wood. Synthetic resin adhesives have made possible the development of densified wood, or "compreg". In practice, thin sheets of veneer are immersed in a bath of phenol-formaldehyde or other resin and subjected to vacuum-pressure treatment which alternately draws and forces resin into the interstices of the wood. When the veneers have picked up from 20% to 35% or more of resin, based upon the original weight of the wood, they are laid up in parallel laminates, or cross-banded as in normal plywood, and cured in a hot press. Full pressure of approximately 1,500 per square inch is developed before the assembly is heated. The temperature is then raised to produce approximately 300° F. of heat in the innermost glue line. Ordinarily presses are maintained at full pressure after completion of the bonding cycle until the center of the panel cools to 120° F. after heating is discontinued.

Compreg made of birch veneer has a specific gravity of from 1.30 to 1.36. It has excellent dimensional stability and mechanical properties except under impact loadings. During the War compreg was used for airplane propellers, parachute flare bases and reinforcing plates. It should be suitable for casters, pulleys, shuttles, bobbins and a host of other items. It has already been found suitable for picker sticks in the southern cotton mills.

Properties and Uses of Plywood. Pound for pound, plywood is stronger than steel. Because of its cross laminate feature, nails, screws and other wood fasteners may be driven close to the edge of a panel without fear of splitting. It has much greater stability than ordinary boards and exhibits little or no tendency to twist or buckle with fluctuations in moisture content. Plywood panels are not limited to narrow widths such as those of boards, but may be produced in wide faces wholly free from defect. Plywood fabrication permits perfect matching, the only method by which beautiful symmetrical grain-patterns may be achieved (Fig. 13).

In the modern post-war home may be found plywood walls, plywood flooring, plywood doors, plywood shelving, partitions and cabinets. Even the outside walls may be fabricated of weatherproof plywood. In our business offices, our public buildings and our shops and stores may be seen an ever changing array of plywood applications—desk tops, tables and chairs, counter tops, wall panels in elevator cabs, store fronts, show cases, window displays, filing cabinets, bulletin boards—all made of plywood.

Plywood is also an important item in the various fields of transportation and is used in enormous quantities in the fabrication of air- and water craft, railway cars, and in trailer and station wagon bodies.

Plywood is now a fully recognized engineering material just as are metal alloys and ceramic materials. Years of painstaking research by wood technologists, engineers and chemists, all working together, have made modern plywood what it is today—a truly superior wood of many and diverse uses.

Henbane—*Healing Herb of Hercules and of Apollo*

This poisonous drug, formerly available only from Europe, India and the Sudan but now produced also in the United States to the extent of 80,000 pounds annually, has been used therapeutically since ancient times and today has common use in modern medicine.

GEORGE M. HOCKING[1]

Introduction

HENBANE is an official drug in the United States Pharmacopoeia where the name "Hyoscyamus" is used for both the English and Latin titles. It is described as consisting of the dried leaves with or without the flowering and/or fruiting tops of *Hyoscyamus niger* L. Likewise official in the U. S. Pharmacopoeia are the herbs prepared from the two other most important medicinal members of the family Solanaceae, namely, belladonna (*Atropa Belladonna* L.) and stramonium (*Datura Stramonium* L.). Of parallel value, therapeutically, they likewise have all been official in the U. S. Pharmacopoeia since this chief official compendium first appeared in its 1820 edition. The importance of Henbane is further witnessed by its being official in nearly if not all present-day national pharmacopoeias, approximately 20 in number.

Besides the leaves, optionally with tops, other parts of the plant have been used, either officially or unofficially, *viz.*, herb, seeds, fruit, root, stalk (Dioscorides), *etc.*, not to mention the expressed juice and the smoke.

Geographical Origin and Distribution

The species *Hyoscyamus niger* is believed to have been originally a denizen of Eurasia, and is now distributed throughout Europe from Portugal and Greece, on the south, to Norway and Finland, on the north. It is found also in the Caucasus, Iran, throughout Asia Minor, in northern India and even in Siberia. The plant has been naturalized in North America, at least since about 1670, and now grows wild in the eastern, northern and western United States and in parts of Canada. It occurs chiefly in waste places, such as near buildings, on roadsides, in graveyards, old gardens, and in areas covered with rubbish from ruined buildings. In habitat, therefore, it considerably resembles its relative, stramonium, except for its more northerly distribution. The plant is now cultivated for medicinal use in a number of countries, including our own.

Common Names

As one might reasonably expect from its importance, the species under discussion has acquired many common or vernacular names. The most important names applied to the plant and the derived drug are in English: Henbane, so-called, maybe, because the seeds are said to kill fowl; Henbain; Hyoscyamus Leaves; Hyoscyamous; Henbane Leaves; Common Henbane; Black Henbane; Stinking Nightshade; Foetid, or Fetid, Nightshade; Insane Root; Poison Tobacco; Soldier's Herb; Soldier's Tree; Hogbean, because the plant is said to be eaten by hogs; Hog's Bean; Hogbane (?); Hen-bell. Older English words almost never heard now include belene;

[1] Formerly Pharmacognosist, S. B. Penick & Company, New York; now Professor of Pharmacognosy, School of Pharmacy, University of Buffalo.

chenil(l)e, apparently stolen from the French; brosewort (?); hanebane; hainbane; henkam; hennebane; hennebone; hennibone and Stinking Roger.

In Latin the species has been variously known as Hyoscyami Folium, a title used by the International Pharmacopeia; Hyosciamus; Herba Apollinaris or Apollo's Herb[2]; Symphoniaca Herba, on account of the resemblance of the flowering and fruiting axis to the musical instrument of that era known as the symphonia; and Jusquiamus.

In France *H. niger* has been called la Jusquiame from the Latin "Jusquiamus"; Jusquiame Noire; Potelée; Herbe-des-chevaux; Hanebane; Hanibane; Hannebanne (Gaston Bonnier), and so on. In German the drug is (Schwarzes) Bilsenkraut; Bilsen; Dullkraut; *etc.* In Dutch the species is known as Bilsenkruid, *etc.;* in Norwegian, Bulmeurt; in Swedish, Bolmört. The common Spanish name is Beleño (Hojas); the Portuguese, Meimendro (Folhas); the Italian, Giusquiamo (Foglias).

Description of Plant

Hyoscyamus niger occurs in two distinct forms. One of them is the annual plant, of interest as having been specifically excluded from some pharmacopoeias (*e.g.*, U.S.P. 1880, 1890, and the eighth revision). The plant seldom grows higher than two feet, is slender in habit and little if at all branched. Its various parts develop on a smaller scale than in the biennial form. The leaves are less distinctly toothed and the corollas show little or no purplish veining. This is the form of the plant which was cultivated by the "herbalists" of a bygone generation.

The biennial form appears to be much the commoner. For instance, Stewart found that when seed of wild-growing Montana plants was sown, the biennial forms were produced.[3] During the first year of growth the plant develops a large whitish, fleshy, tapering, branched root, somewhat resembling that of a parsnip or small horse-radish, crowned by a radical rosette of large leaves, a foot or more long, with very long petioles and coarsely toothed, lobed or deeply cut blades. No aerial stem is produced. During the second year the plant throws up an erect, thick, coarse and widely branched stem, two and a half to four or even five feet tall, which bears flowers in long, secund, leafy, spike-like groupings. The flowers in this form have prominent purple vein markings on the corolla. Fruits are formed within the permanent calyx, and as these mature, the entire plant dies. At this stage the root becomes spongy and then hollow, and the radical leaves disappear, while those on the stem are found to be quite broad with relatively short petioles or even sessile near the top of the stem.

Wild growing plants near Bearmouth, Montana, were found by Stewart to have, instead of one flower stalk, as customary, several stalks (up to twelve) growing from a single root-crown. It was suggested that this was due to cropping of the first year's growth by sheep. The plants ranged from two to five feet in height, the taller growing in a shady ravine, the smaller in the sunlight on a hill-top. Undoubtedly the rich fertilized soil of the sheep corral, in which the plants grew, accounted in part for the luxuriant growth. No infestation or plant disease was noted, although such have been reported for plants growing farther east in Montana. Catnip, mullen and horehound were growing alongside. The plant thrives well in Montana to over 7,000 feet elevation, and in India it has been reported from altitudes of 8,000 to 11,000 feet.

[2] Apollo of the Greeks = Hercules of the Romans.

[3] These and other data in this article relating to Montana Henbane, unless otherwise stated, were gleaned from the unpublished M.S. Thesis of George W. Stewart of the State University of Montana, 1934, kindly loaned to the author.

Cultivation

Some people who have cultivated a variety of medicinal plants state that henbane is one of the most difficult of its family to rear successfully, *i.e.*, to produce a drug meeting official requirements.

Experiments in cultivation have been carried out in the Drug Garden of the School of Pharmacy at the State University of Montana (Missoula). The seed used was collected from a plot of wild-growing plants near Bearmouth, about 40 miles from Missoula. Seed was gathered the last of August and sown on April 15 of the following year (*ca.* 1933). Before planting, it was treated with 5% sulfuric acid for 20 minutes, then washed with water and dusted with lime to neutralize and provide calcium for the seedlings. Small shoots developed in about three weeks. The plants were thinned out several times during the season. Growth continued until the summer, when an arrest of growth occurred with the plants one-half to one foot high. The following spring the plants sent up flowering stalks which bore blossoms in July. These biennial plants appeared free from disease or infestation, although untreated by spraying, *etc.*

The transplanting of henbane seedlings from a greenhouse or cold-frame to the outdoor area has not been very successful, for most plants do not survive the shock of moving, and those that do are stunted in growth. This is said to be caused by injury to the tap root. Better results are achieved if plants are allowed to attain fair size before being moved.

Because of this obstacle to large-scale propagation, the Wisconsin Pharmaceutical Experiment Station at Madison years ago undertook experiments to determine whether the seed might not be sown directly in the fields, as is done with stramonium. Biennial seed was accordingly sown in early December, 1916, and began to come up about May 10, 1917, while some of the same seed sown on April 21 came up on May 16. Besides taking only one week more to emerge from the soil, the spring-sown seed gave a more uniform stand.

In growing henbane it is best to select a level area, as free as possible from weeds. A well drained fertile sandy loam or silt loam is considered best. One pound of seed is enough per acre and should be sown in rows two feet apart. If kept dry, henbane seed remains viable for several years, a fact which accounts for certain reported vagaries of growth. It is best to test germination of the seed before sowing. The best seed is that which has been specially collected for planting purposes. Pre-treatment of seed with concentrated mineral acid was reported to result in germination in about 20 days rather than the usual 30.

Sowing may be done by mixing the seed with sand and dropping it into shallow holes. Better still, a small seeder will give more uniformity. The seeding should be at such a concentration that one viable seed is laid every four inches along the row, and the seeds must not be covered by more than about one-quarter inch of soil.

Cultivation may be carried on before the young plants appear, if the rows can be distinguished or have been properly marked. Later on, regular weeding should be practised, and if necessary the plants ought to be thinned out so as to leave them about four inches apart.

Harvesting of leaves and flowering tops is carried out when the plants are in full bloom (June to August) and before the first frost. Drying is best performed in a drying house, where the herbage may be spread in thin layers on floor, trays, *etc.* Drying is hastened and color and quality improved by using a small amount of heat and air currents.

A yield of 600 pounds of Henbane per

acre may normally be expected. Almost twice as large a crop per acre may be obtained from the first- as from the second-year plants.

Infestations and Diseases

From the literature it appears that the Colorado potato beetle is henbane's worst enemy; it has been said to prefer henbane to all other plants. If the plants are not to be entirely destroyed by this pest, they must be sprayed with an insecticide. In the past, lead arsenate has been mostly used. Paris Green was found destructive to the plant, and sulfur soon loses its effect on the insects which prey on it. Two sprayings of 1 to 1,000 suspension of lead arsenate during the life-time of the plant are said to be adequate. Among the fungi reported as attacking *Hyoscyamus* are *Peronospora* (Phycomycetes) and the mildew *Erysiphe* (Ascomycetes).

Commerce

Before World War II most Henbane drug imported into the United States came from Europe, chiefly Hungary, Belgium, France, the Soviet Union, Germany and Italy. During more recent times exports have come chiefly from India, the Sudan, the United Kingdom, the Soviet Union and elsewhere, but the largest bulk has been domestically produced in the continental United States. At present the U. S. exports only a few thousand pounds of the approximately 80,000 produced here annually.

Montana is or recently has been the chief producing area for domestic Henbane, although the plant grows wild commonly in sections of the other northwestern States, *i.e.*, Idaho, Washington and Oregon. The plant is said to have first been observed growing in Montana at Big Timber, in the year 1883. The plant grew from a pile of dirt thrown from the basement of an hotel under construction. It is thought that a workman engaged in the labor dropped smoking tobacco admixed with the seed, since it is known that henbane seed has sometimes been mixed with tobacco to bestow a narcotic effect.

The species was subsequently collected in 1900 at Billings, Big Timber, Bozeman and elsewhere in Montana, and was spread to other parts of the State by admixture with hay, it is thought. Thus, the patch at Bearmouth is believed to have come from seed of plants mixed in hay for feeding horses used by convict labor when the Missoula-Deer Lodge road was built.

Henbane has sometime been marketed in grades representing stages of growth: (*a*) "Annual" or "seedling"; (*b*) "First Biennial", for leaves or herb of the biennial plant in its first year of growth; (*c*) "Second Biennial", for leaves of second year. The last item is scarce and high priced. In opposition to earlier opinion, first-year leaves have an alkaloid content similar to that of second-year leaves and are now considered equally as useful medicinally. However, they contain more acid-insoluble ash (sand, dust, *etc.*), no doubt because they are entirely basal leaves and not partly basal, partly stalk-leaves.

Description of Drug

The crude drug consists of much wrinkled, matted and broken leaves mingled with many stems and flowering and fruiting tops. The leaves are ovate to ovate-lanceolate, up to 26 cm. long and 10 cm. wide, not evenly divided by the mid-rib, the lower leaves petiolate, with petioles up to one-third the length of the blade, and the upper leaves stalk-less. The tips of the leaves are acute, the margins irregularly dentate (toothed) or pinnatifid (deeply lobed), with acute deltoid lobes. The upper surface of the leaf is darker than the lower. The leaf color is a shade picturesquely described by Parkinson

(1640) as a "darke or evill grayish greene colour". The same Apothecary and Botanist to the King gave the odor of the entire plant as a "heavie evill soporiferous smell somewhat offensive". Others have called it "dank", "benumbing", "narcotic", "noisome", "horrid", "heady", peculiar, strong, unpleasant, rank, distinctive, heavy, fetid, and so on. The aroma of Henbane has been compared to that of fresh tobacco, black currant leaves, and musk. The taste of the crude drug is bitter and acrid.

Henbane flowers are nearly sessile, with an unequally five-toothed, urn-shaped, hairy calyx, and a yellowish, campanulate, slightly zygomorphic corolla, with purplish veins. The corolla ends in five unequal obtuse lobes, and five stamens are inserted in its tube.

The fruit consists of a two-chambered pyxis (urn-shaped type of capsule which dehisces or opens by separation of a lid-like top) enclosed in the persistent calyx. When found, the seeds are black (hence the specific name of the plant) to dark gray, round-oval, numerous, tiny, unequal and hard.

The stems are two to seven mm. in diameter, somewhat compressed or cylindrical, longitudinally wrinkled and hairy.

The powdered drug is dull grayish-green to dark green. When examined under the microscope, it reveals calcium oxalate crystals in the form of monoclinic prisms, as twin crystals and as rosette aggregates (the latter not common). Non-glandular hairs are found, ranging from one to ten cells in length—these are often broken up in the powdered drug. Glandular hairs with a one- to four-celled stalk and a unicellular or multicellular secreting head also occur. Newcomb observed that very large branching non-glandular hairs, which had not previously been described for this plant, presumably because they are of relatively soft structure, are found on green plants and apparently soon disappear when the plant is dried and handled.

Also observable microscopically are epidermis fragments with broad elliptical stomates having three or four neighboring cells, one of which is smaller than the others; fragments of tracheae with pores, reticulations and spiral markings; bast fibers; and pollen grains which are nearly smooth and bear three furrows.

Chemical Constituents

Henbane contains several important constituents, the two most important being the alkaloids hyoscyamine (crystalline) and scopolamine or hyoscine (amorphous). Minor other alkaloids, *e.g.*, scopoline and tropine, are present in traces.

Scopolamine was first isolated from the herb in 1833, and was obtained first from the seeds in 1871. It is a syrupy compound in the free state, but a crystalline solid in the form of the common salts. Scopolamine hydrobromide is official in the U. S. Pharmacopoeia and is used considerably in medicine, both by mouth and hypodermically. Henbane is not, however, the chief source, since this alkaloid is obtained mostly from *Datura* species, a related group in the Solanaceae.

The other alkaloid, hyoscyamine, is not now commonly used in medicine and is no longer official in the national compendia which serve as standards for American drug products.

Other components of Henbane which have been isolated are hyoscipicrin (a glycoside), choline, mucilage, albumen, chlorophyll and potassium nitrate. The last compound (salt peter) is presumed to cause the characteristic sparkling effect seen when the dried leaf is ignited. The seed contains much fatty oil (about 25%) and also a little volatile oil.

Analyses of Domestic Drug

According to U. S. Pharmacopoeia XIIII, the drug Henbane must contain

not less than 0.040% of the alkaloids characteristic of the plant. This is a lower requirement than that in earlier pharmacopoeias (*e.g.*, U.S.P. IX, X, where not less than 0.065% alkaloids was required, or U.S.P. VIII set 0.080% as a minimum).

Analyses of Montana Henbane, the chief domestic type, show that most lots are comfortably above the minimum required strength, as at present defined. Thus, one crude-drug concern[4] has furnished the following values for commercial batches of the Montana product:

Number of lots		*Test (% total alkaloids)*
1		0.042
4		0.054
7		0.060
3		0.061
5		0.065
4		0.073
1		0.078
1		0.090
Total 26	Average for all lots	0.0633

From this it appears that 15 or more than half of the lots were below the former official strength, while the average assay of all lots was less than the former required figure. On the other hand, all lots meet the present minimum assay requirement, and one of them is more than twice as high as the needed assay.

Stewart found that the U.S.P. X assay method was unsatisfactory in assaying the Montana drug with which he worked[5], due to the formation of very stubborn emulsions in "shaking out" the alkaloids. By this method the Montana drug assayed only 0.005% (average), while commercial imported Henbane ran 0.0867% or about 17 times as high. To help remedy this, the drugs were first defatted with petroleum ether. Assays then ran higher (0.030% average for domestic; 0.078% in commercial drug).

In order to partially simulate conditions undergone by the commercial drug, the Montana material was heated at 95° for two weeks to drive off volatile matter. After this treatment the drug was of much the same color as imported material and had lost much of its offensive odor. In conducting assays with this, no difficulty was had with intractable emulsions, as before. Material so treated averaged 0.044% alkaloids (imported drug 0.071%).

Finally Stewart tried the method of C. M. Caines (1929), which seemed an improvement over other methods, and this gave results indicating a Montana product almost meeting the then current official standards, since the average of determinations was 0.057% (imported drug 0.081%).

Stewart also made other chemical studies on the Montana Henbane (same material as that used for alkaloidal studies). He obtained the following values:

Loss on air drying (25° C.)	88.18%
Total volatile matter[6]	10.89% (aver.)
Total ash	19.25% (aver.)
Acid-insoluble ash (not more than 12% allowed, U.S.P. X–XIII)	2.73% (aver.)

Successive extractions by Soxhlet method:

Petroleum ether	5.67%	(average	imported,	3.35%)
Ethyl ether	5.10%	"	"	2.49%)
Alcohol	23.91%	"	"	16.87%)
Dist. water	20.68%	"	"	20.99%)

Other findings were:

Crude fiber	6.11%	"	
Total nitrogen (in leaves)		4.24%	(average)

[4] S. B. Penick & Company, New York; data furnished through the courtesy of Dr. Thomas Lewis, Vice President and Technical Director.

[5] Material was collected from wild-growing plants close to the Butte-Missoula highway near Bearmouth. The leaves and flowering tops were collected June 28, 1933, dried and ground to a #40 powder.

The seeds of Montana henbane were also studied by Stewart. He reported in his Thesis the following values from chemical tests carried out on the seeds ground to a fine meal (all figures are averages):

Volatile matter (100° C.)[6]	10.39%	
Total ash	2.87%	
Acid-insoluble ash	0.41%	
Successive extractions by Soxhlet method:		
Petroleum ether	32.63%	The bulk of this extractive (non-volatile) is of course the fatty oil.
Volatile portion	1.95% (of crude)	
Ethyl ether	31.14%	
Volatile portion	3.42% (of crude)	
Alcohol	24.61%	
Distilled water	6.60%	
Crude fiber	25.33%	
Total alkaloids	0.093%	(after defatting seeds)
" "	0.130%	(by Caines' method)

The fatty oil was extracted from the seeds with petroleum ether, then the solvent evaporated and the oil filtered through cotton. The fixed oil constituted about 25% of the seeds (W/W). It was amber-colored with a bland innocuous taste and very little odor. The following constants were reported by Stewart:

			Values of Bureš and Kracík (cold extraction)
Spec. Gravity (25° C.)	0.9183		0.9120–4 (d15°)
Refract. Index (25° C.)	1.4739		.....
Saponification No.	191.72	(average)	187.8
Iodine Absorption No.	82.07	(average)	135.7

The figures for the Montana seed oil and that of Bureš and Kracík for plants grown in Czechoslovakia are far from concordant, but may be partly explained by the differing habitats and latitudes.

[6] Determined by heating in oven at 100° C. until of constant weight.

Derivatives and Preparations

It is typical of the human being to attempt to improve on nature, and in the field of medicine we find no exception. Instead of administering the whole leaf of henbane, or its powder, it has been customary to give either the so-called galenical preparations, such as tinctures, extracts, *etc.*, or the alkaloids. From an historical standpoint the preparations are of much greater importance, and the elegance and imaginative titles which have distinguished many of them are quite interesting. A mere listing of the titles, in some cases translated into English, is very revealing of the human ingenuity displayed in the administration of this one drug:

Modern or Current:
- Tinctures
- Fluidextracts
- Extracts (both semi-solid and powdered)
- Fomentations
- Compound Oils (Infused Oils, *etc.*)
- Abstracts
- *etc.*

Formerly popular (as described in the Universal Pharmacopoeia, published at Weimar in 1845):
- Anticephalagic Paste (for frontal headache)
- Anodyne Cataplasm
- Electuary for Hemoptysis (spitting of blood)
- Conserve (made with white sugar !!)
- Oil of the Seed
- "Paregoric Oil"
- Hemorrhoidal Ointment
- Juice
- Seed Extract
- Fecula (a starchy preparation)
- Syrup
- Narcotic Boli (large pills)
- Pills
- Pills of Extract
- Narcotic (or Sedative) Pills
- Antichoreic Pills (for St. Vitus' Dance)
- Anti-hysteric Pills
- Anodyne Pills
- Anodyne and Resolvent Liniment
- Pomade
- Antispasmodic Elixir
- Collyrium (Eye Wash)
- Sedative Narcotic Haustus (Draught)
- Breast Draught
- Expectorant Draught
- Enema
- Infusion
- Sedative Emulsion
- Anti-odontalgic Collutorium (Mouth wash for toothache)
- Narcotic Cataplasm
- Alcoholic Extract
- Essence

Tincture of Seeds
Ethereal Tincture
Green Oil
Ointment
Plaster
Unguen tum ad Ambusta seu Combustiones (Ointment for burns or burnings)
Anodyne Ointment
Tranquil Balsam
Ear Oil
Sedative Liniment
Compound Poplar Ointment
Hemorrhoidal Lotion
Etc.

Uses in Medicine

The physiological action of Henbane is similar to that of Belladonna, Stramonium, Scopola and similar drugs of the Solanaceae. While less powerful than they, Henbane is relatively more sedative and hypnotic and causes little or no constipation and other unwanted by-effects.

Ancient Uses. Henbane has been employed as a medicine from very early times. Baron Hammer-Purgstall actually believed "bendj" (Arabic for Henbane) was the Nepenthe of Homer. White Henbane was one of the "simples" used by Hippocrates (5th Cent., B.C.). This plant is quite similar to our Henbane in medicinal effects.

Dioscorides (A.D. *ca.* 60) called the plant "hyoscyamos" (literally "hog's bean"), but he also mentions "dioskyamos" (bean of the gods) as an outmoded name, possibly so-called from the usage of the drug in the temple "mysteries" or religious rites. In his works Dioscorides described three species—black, white and yellow. Of these he particularly commended the "white" as being the least dangerous. (As a matter of fact, it closely parallels black Henbane medicinally, although rather weaker in action). Dioscorides recommended the root with vinegar as a mouth-wash for toothache, and 17 or 18 centuries later we find still prescribed an Anti-odontalgic Mouthwash made from a mixture of henbane and plantain leaves with violet and red rose flowers, poppy heads and sage leaves in water, properly processed. Not as useful perhaps as the modern novocain or even clove oil, yet this preparation doubtless eased the pain of many a case of odontalgia. Another application of Henbane for the same purpose during the past few centuries has been that of burning the seeds and funneling the fumes into dental cavities in an effort to expel the "tiny worms" believed to cause the distress resulting from caries.

Pliny (fl. 60 A.D.) recognized the psychogenic qualities of the drug when he wrote:

"Henbane is of the nature of wine, and therefore offensive to the understanding, and troubles the head. . . . [It ought] to be used with great heed and discretion. For this is certainly known, that, if one take of it in drink more than four leaves, it will put him beside himself".[7]

An early contraceptive was made by mashing the seeds into paste with mare's milk and tying the paste in a piece of wild bull's skin.

In the Middle Ages Henbane was used legally as an anesthetic (with opium, mandrake, hemlock juice, aconite, datura, *etc.*) in the form of a "soporific sponge" and of the "pomander" (sleeping apple), acting through inhalation; it was also employed illegally as a sleeping potion, much as "knock-out drops" are used in our time. Gui de Chauliac of the 14th Century thus described the use of a narcotic inhalation:

I'll imitate the pities of old surgeons
To this last limb, who, ere they show their cut,
Cast one asleep, then cut the diseased part.

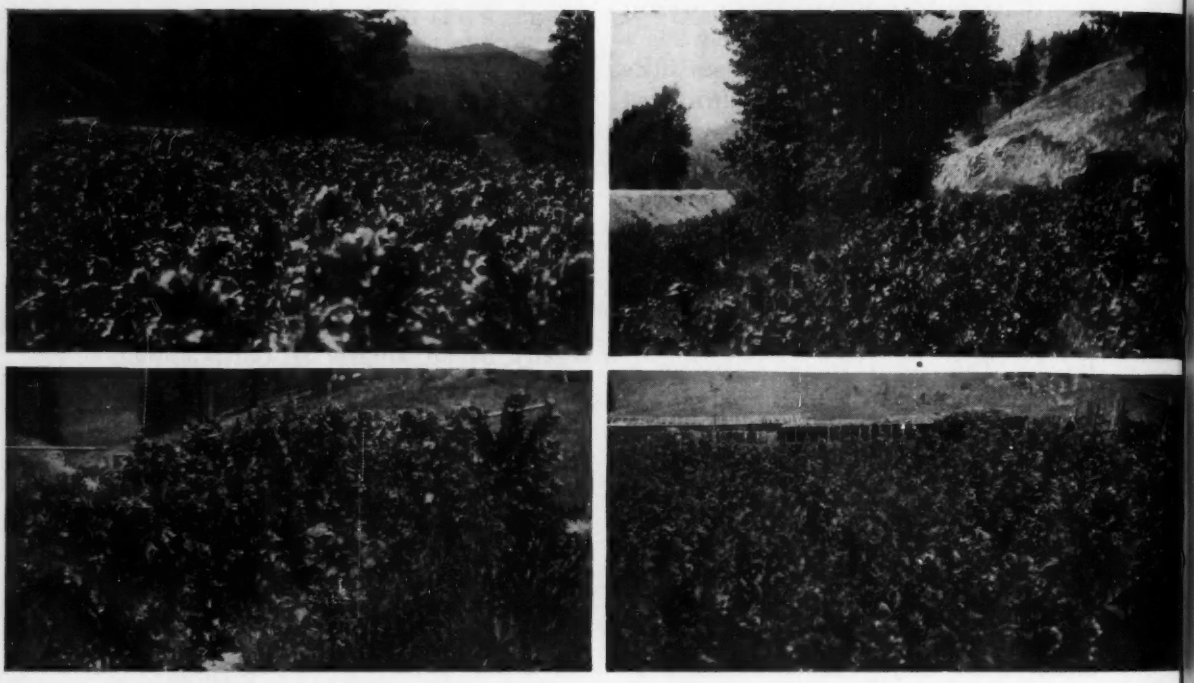
The medicinal popularity of Henbane dropped after the Middle Ages along with that of Belladonna, until by the 1700's it fell into disuse and was omitted from such compendia as the London Pharmacopoeias of 1746 and 1788, being returned only in the edition of 1809. Henbane was reintroduced into occidental medicine chiefly as the result of original labors by Professor Baron

[7] Holland's translation (1601), revised.

Stoerck of Wien, who in 1762 carried out an investigation of the remedial value of Henbane, Stramonium and Aconite.

The Arabians, too, were familiar with the medicinal value of Henbane, as may be gathered in part from the following extract from that great anonymous classic, "The Thousand and One Nights":

"Presently he filled a cresset[8] with firewood on which he strewed powdered Henbane, and lighting it, went round about the tent with it till the smoke entered the nostrils of the guards, and they all fell asleep, drowned by the drug".



FIGS. 1–4. Henbane growing wild in a sheep corral and elsewhere near Bearmouth, Montana. (*Courtesy G. W. Stewart.*)

Modern Uses. During the past century and a half Henbane has found many uses in western medicine, uses depending on its value as an anodyne (pain reliever), hypnotic (sleep promoter), narcotic, mydriatic (eye pupil enlarger), mild laxative, carminative (digestion aider), sedative (nerve quietener) and antispasmodic (spasm antidote). Thus, Henbane has been used as a sedative in acute and chronic mania, epilepsy, hysteria, "hypochondriac monomania," delusional insanity ("madness")[9], melancholia, nervous or irritable cough, tremor in paralysis, febris nervosa (where fever arises from purely nervous disturbances), insomnia with hallucinations, delirium tremens, priapism, *etc.* It is used for its anodyne properties in angina pectoris, arthritis, rheumatism, locomotor ataxia, colica pictonum (colic of lead poisoning, lead colic, or painter's colic), other colics, podagra (or gout), neuralgia, gastralgia (stomach ache), cephalgia (headache), teething of babies[10], *etc.* As an anti-

[8] A holder for torches and other burning objects.

[9] Strange to say, Henbane is also said to cause insanity.

[10] Formerly, pieces of the root were strung around the neck of the baby to form the so-called "anodyne necklace".

spasmodic it was and sometimes still is used in asthma, chorea (St. Vitus' dance), tetanus, constipation, whooping cough, phthisical coughs, croup, *etc.*

Hyoscyamus is sometimes used locally for applying to painful swellings, irritable ulcers, tumors, severe chordee, orchitis, *etc.*

A most important modern usage of Henbane and other solanaceous drugs is as a corrective for griping medicines, such as strong purgatives. It serves as an antidote in poisoning by mercury and other agents, and is occasionally used in treating the morphine habit.

Henbane is sometimes used also as an hypnotic, *etc.*, where opium derivatives cannot or are best not used, as for children.

Among the so-called "mydriatic" or "solanaceous" alkaloidal drugs, Henbane is ranked in importance next after Belladonna. The average dose is 0.2 Gram.

Non-medicinal uses include its employment for ages by professional poisoners. And finally, the leaves of the plant are said to repel mice.

Poisoning

The toxic properties of white Henbane have been recognized since long before the time of Christ. Poisoning comes about generally from the ingestion of doses larger than medicinal, and as a rule are seen where an overdose of medicine is taken, or where a part of the plant is accidentally consumed, as by children. Most recent poisonings described have been from one of the alkaloids.

Poisoning begins with the development of mouth dryness, burning throat, pupil dilatation, visual disturbances, giddiness, nausea and hallucinations. If remedial measures are not taken and the dose is sufficiently large, more serious symptoms ensue, such as difficult respiration, delirium, feeble quick pulse, coma, convulsions and finally death by paralysis of respiration. Fairly characteristic is the reddening of the skin of face and neck, somewhat reminiscent of that in scarlet fever, but in later stages of poisoning the skin becomes cold and clammy, although the rash may persist even after death. Most characteristic of all, at least for the solanaceous group, is the persisting enlargement of the pupil of the eye. This mydriatic effect commonly continues for several hours after death.

Treatment is best conducted by washing out the stomach with a stomach-pump, using tannic acid in the wash water. As antidotes, morphine or caffeine may be used with care.

Adulteration

Henbane is sometimes adulterated, although less often than formerly. *Hyoscyamus muticus* L. (Egyptian or Cyprus Henbane) leaves and tops have sometimes been seen admixed with the true Henbane. This is a particularly dangerous adulterant, because this plant is very much richer in alkaloid than our Henbane. Also, other unofficial Henbanes have been used at times to adulterate or sophisticate true Henbane. Also so used have been Stramonium, Belladonna, Mullen and Digitalis. Adulteration is best detected by means of the microscope, since when dried and crumpled, these various leaves have considerable similarity to the unaided eye. Thus, microscopically, Henbane is very readily distinguished from both Belladonna and Stramonium by its much greater coverage of the leaf by trichomes.

Other Hyoscyamus Species

Approximately 20 species of *Hyoscyamus* are recognized. One species, *Hyoscyamus albus*, has already received passing notice. It was used by the ancients for catarrh, cough, *etc.*, and the

natives of southern Europe, where it grows, still sometimes use the plant in much the same manner as we do our medicinal Henbane. They also grow it as an ornamental in flower gardens, and additionally *H. aureus* L., which also is occasionally used as a drug. The root and herb of *H. physaloides* L. was once used in Siberia in place of opium as a medium of exchange. *H. muticus*, already mentioned as an occasional adulterant of Henbane, is imported into this country in considerable quantities for use in alkaloid manufacture, as is well known. The alkaloid content is roughly 25 times as great as that of "Henbane Niger", as true Henbane is sometimes referred to in commerce.

Utilization Abstracts

Bamboo Pulp. "The future for white paper made of bamboo is bright. Runs made a few months ago were so successful that one concern is contemplating cultivation of bamboo in Texas for commercial use. Only a few of the 123 varieties now being grown in a United States Experimental Station near Savannah, Georgia, have been tested, but further research is now being carried on". (*Pulp and Paper Bulletin, as reported in Chemurgic Digest 5(13): 235. 1946*).

Cork Oak in Maryland. Through the cooperation of the Crown Cork and Seal Company of Baltimore and the Maryland Department of State Forests and Parks, experimental plantings of cork oak, *Quercus Suber*, have been made in Maryland. It has been found that the southern counties and the Eastern Shore of the State are suitable for growth of this tree which is native to the western shores of the Mediterranean. It is hoped that this may indicate possible future commercial production of cork in the State, not only as a forest crop but also on farms where the acorns would be of value as hog food.

"For normal peacetime manufacturing requirements in the United States about 160,000 tons of cork are imported annually. Sixty percent of the cork brought to this country is used in the manufacture of cardboard insulation. Other uses of cork include: floats for gauges and fishing nets, life jackets, shoe inner soles, printing press blankets, closure liners, ring buoys, gaskets of many kinds for automobiles, tractors, trucks, household appliances and industrial equipment, linoleum, cork tile, sporting goods and novelties". (*G. B. Cooke, Chemurgic Digest, 5(10): 187. 1946*).

Charcoal. Charcoal is produced either as the residue from wood distillation operations in large retorts, or by incompletely burning wood under an earth blanket to carbon without any consideration being given to the volatile products driven off. In the northeastern States there are four main uses of charcoal:

First, in shade-tobacco curing sheds. About 7,500 tons are annually used for this purpose in the Connecticut Valley, some of it in the form of briquets obtained, when available, from the Ford Motor Company in Michigan. These briquets are molded from powdered charcoal with starch or other material as a binder.

Second, as fuel for home cooking by the foreign-born population.

Third, in industrial operations, chiefly brass and other metal industries, where charcoal possesses qualities particularly valuable to the processes.

Fourth, as a purifying agent. Pulverized charcoal, treated to drive off the hydrocarbons, is converted into "activated charcoal" which possesses absorptive qualities as a refining and purifying agent. Water companies use it to remove tastes and odors from drinking water. (*E. L. Heermance, Chemurgic Digest 5(10): 188. 1946*).

Agar—*A Pre-War Japanese Monopoly*

A seaweed product of ever-increasing importance, half a million pounds of which are annually used in the United States in foods, medicines, cosmetics, dentistry and other industrial operations.

HAROLD J. HUMM
Duke University Marine Station

Introduction

Knowledge of the earliest use of seaweeds is lost in antiquity, but it seems likely that their use as food goes back to prehistoric times. During the past 300 years, Oriental peoples have learned to obtain extractives from seaweeds and to use seaweed products in medicine, as adhesives, and as a sizing for paper and fabrics as well as in foods. Today, the most important product obtained from seaweeds is agar, a widely-used commodity but one that is not well known to the general public.

Prior to World War II, Japan enjoyed a world monopoly on agar of commerce by virtue of the development of the industry in the Orient and the abundant supply of agar-bearing seaweeds along Japanese coasts. With the introduction of agar into bacteriology in 1882, it became a commodity of great importance to the welfare of Western peoples. At the same time, its wide use in laboratories led to the development of many other uses. Agar was a rare commodity in America 60 years ago, as it was used only as a novelty food, usually in making jelly desserts.

Agar is obtained only from certain species of a group of seaweeds known as red algae (Class Rhodophyceae). It is a complex polysaccharide that forms a collodial solution in hot or boiling water and has a remarkable gel-forming capacity, some eight to ten times greater than that of gelatin. The chemical structure of agar is so complicated and imperfectly understood that synthetic agar has not yet been produced.

With the outbreak of World War II, agar was one of the first commodities to be designated a "critical war material" by the War Production Board. Its use was restricted to bacteriological culture media. During the preceding 20 years, over 90% of all agar used in the United States had come from Japan. As a consequence of the war, the agar industry in the United States, which had begun in California in 1920, was revived and expanded. At the same time, governmental agencies and private institutions began a search for new sources of agar raw material and agar substitutes. The establishment of the agar industry on the Atlantic coast of the United States was a result.

The future of the American agar industry is uncertain. Already importations from Japan have been resumed and, although it may be several years before unlimited quantities from abroad are available, the spectre of a return of prewar competition faces the American producer. Higher protective tariffs, lower costs of production, new uses and increased demands for agar, and new agar products for which imported agar cannot be substituted are factors that can do much to keep our industry in full production in years to come.

Terms

The term "agar" is most frequently applied to gel-forming extractives of red algae that are similar in properties to the Japanese product made principally from *Gelidium Amansii* Lamour. or California agar made from *G. cartilagineum* (L.) Gaill. The term is generic. To attempt to give the word "agar" a precise chemical definition (such as the chemical structure given by Jones and Peat[1], for example) seems rather pointless, since such a precise definition is not likely to be applied generally. Although the physical properties of agar from *Gelidium* and certain species of *Gracilaria* are so similar that extractives from both will always be called agar, the chemical structure of agar from different seaweeds is probably not identical.

The definition for agar given by the United States Pharmacopeia[2] is not ideal in that it deals vaguely with some important properties, such as gel strength, and over-emphasizes less important characteristics, such as acid-insoluble ash. Agar that meets U.S.P. specifications can be ideal for bacteriological use or it can be quite unsuitable. Likewise, agar that does not meet U.S.P. requirements might prove excellent for bacteriological use.

It seems that the most practicable definition is a modification of that proposed by Tseng[3] to be stated somewhat as follows: Agar is the gel-forming extractive from *Gelidium, Gracilaria,* and other red seaweeds that is insoluble in cold but soluble in hot water, a 1% solution of which forms a firm gel.

The foregoing definition excludes the colloidal polysaccharide extractives from certain red algae, *e.g., Chondrus crispus* (L.) Stackh. ("Irish moss"), *Gigartina, Agardhiella, Iridophycus, Gloiopeltis, Phyllophora* and some species of *Gelidium* and *Gracilaria.* These extractives form a weak gel in concentrations of less than 2% but are of value for purposes in which gel strength is not an important characteristic. The Russians have appropriately called the extractive from *Phyllophora* "agaroid", a term which seems suitable for any agar-like extractive that forms gels too weak to be regarded as agar. Tseng suggests the term "carrageenin" to designate Irish moss extractive and "iridophycin" for the extractive from *Iridophycus,* both agaroids.

"Gelose" seems to be an appropriate term to refer to any colloidal polysaccharide from red algae. Tseng has proposed the convenient term "phycocolloid" to refer to any colloidal polysaccharide derived from algae, a word that includes algin from the brown seaweeds as well as agar and agaroids. Agar-yielding seaweeds he terms "agarophytes".

Early History of Agar

The discovery that agar can be purified and dehydrated by freezing and thawing came about by accident in Japan about the middle of the seventeenth century when a Japanese inn-keeper discarded some left-over agar that had been prepared for food. As the story goes, it was a cold night and the gel froze. The next day the inn-keeper noticed that after having been thawed and dried by the sun, it became a light, porous mass. He placed some of the dehydrated agar in boiling water and discovered that it made the same sort of gel as when first extracted from the seaweed. In this manner, as pointed out by Tseng[4], the fundamental procedures were discovered that led to the establishment of the agar industry in Japan.

With the knowledge of how to prepare dehydrated agar, an industry soon de-

[1] Jones, W. G. M. and S. Peat. Jour. Chem. Soc. 1942: 225–231.

[2] Pharmacopeia of the United States. Ed. XII. 1942.

[3] Tseng, C. K. Science **101**: 597–602. 1945.

[4] Tseng, C. K. Food Ind. **17**: 10–11. 1945.

veloped in Japan, and the use of agar grew rapidly, since it could be kept indefinitely in pure, dry form and could be transported cheaply to inland localities. Foreign demand for agar began to develop during the nineteenth century, and the Japanese began to export in small quantities. It was at the beginning of the twentieth century that export business became an important part of Japan's agar industry.

manufacturing process, including a "dewaterer" and dehydrating tower, patented in 1929. Other factories have been established in California in recent years.

Although California factories produced only about ten percent of the 600,000 pounds of agar used in the United States in 1941, the outbreak of war found these producers ready to expand to such an extent that they were able to meet our domestic wartime requirements and to

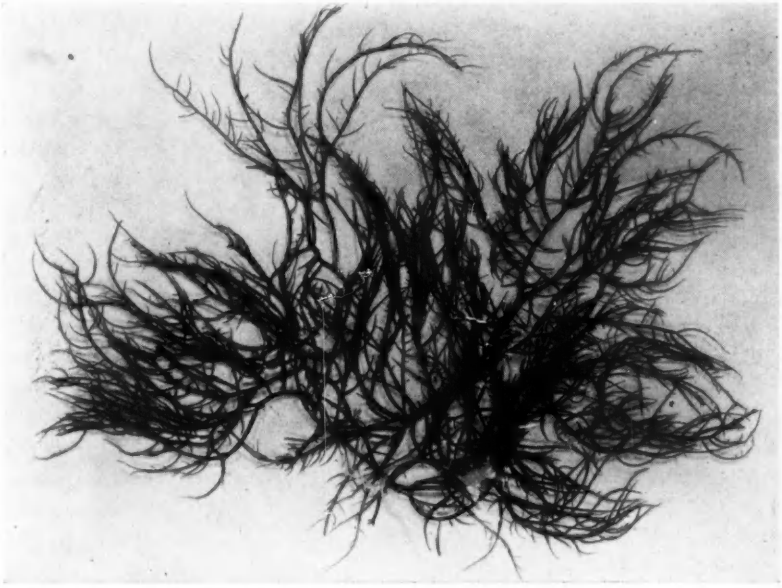


FIG. 1. *Gracilaria confervoides*, the sterile, free-floating phase. (*Courtesy Duke University Press.*)

Development of the Industry in the United States

Chokichi Matsuoka, familiar with the agar industry of the Orient, observed that an abundance of *Gelidium cartilagineum* grew along the coast of California. He organized a company in 1919 that first began to produce agar in 1920. Matsuoka acquired several patents relating to agar production, but his business failed within a few years. The factory was sold to John Becker, an engineer, who made a number of important labor-saving improvements in the

provide small quantities for export to allied nations.

Along the Atlantic coast of the United States a search for agar-bearing seaweeds began in 1942. *Gracilaria confervoides* (L.) Grev. was found in abundance of commercial value along the coast of North Carolina near Beaufort[5]. Late in 1943 the Van Sant Company at Beaufort, working with an affiliated firm, the American Chlorophyll Company of Alexandria, Virginia, began to produce agar. The Beaufort factory had been built for

[5] Humm, H. J. Science 96: 230–231. 1942.

other purposes, but since war had curtailed its original work, it was quickly adapted to produce agar exclusively. In 1945 the name was changed to Beaufort Chemical Corporation and its production capacity increased.

Exploratory work for agar resources continued along the Atlantic coast in 1942 and 1943 with financial aid from the War Production Board. A survey of the coast from Maryland southward, around the State of Florida and along the Gulf coast to New Orleans, resulted in the discovery of additional seaweed resources from which agar or an agaroid could be produced[6]. The greatest abundance of seaweed was found along the west coast of Florida south of Clearwater, especially in Tampa Bay. The most common species include *Gracilaria blogettii* Harv. and *G. foliifera* (Forssk.) Børg. The extractive of these species from the west coast of Florida is an agaroid, as it is inferior in gel strength to agar. Considerable quantities of *G. foliifera* from which agar can be produced were found also along the east coast in the Indian river between Daytona Beach and Stuart. The gel strength, however, is somewhat inferior to that of agar from *G. foliifera* of North Carolina.

Experimental and small-scale agar production took place on both the west and east coasts of Florida during the war. Experimental work was done at Citrus Concentrates, Inc., at Dunedin,

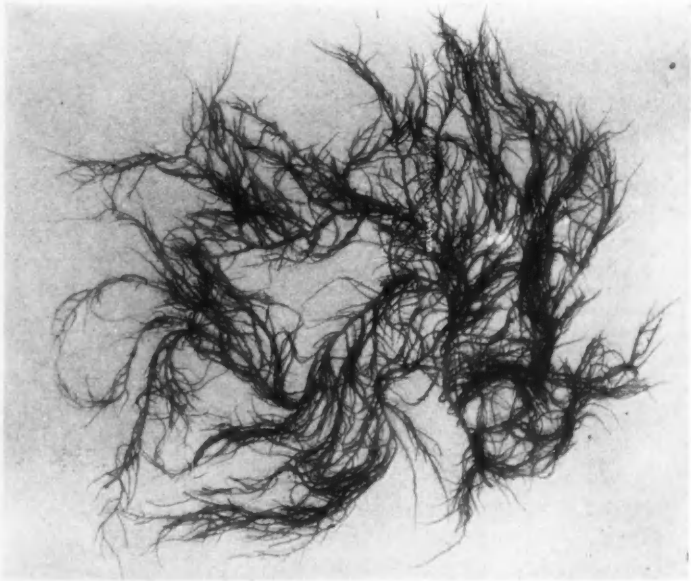


FIG. 2. *Hypnea musciformis.* (*Courtesy Duke University Press.*)

and production on a small scale was undertaken by Sperti, Inc., near Jensen on the Indian River. However, significant quantities of agar were not produced in Florida before the end of the war, and apparently Florida production is still unimportant. An exclusive right to collect seaweed from the beds of known commercial value in the Indian river was issued to Sperti, Inc., by the State of Florida.

In 1943 a subsidy was received from the Office of Production and Research Development by Duke University and its marine biological laboratory at Beaufort, North Carolina, to expand a pro-

[6] Humm, H. J. Science **100**: 209–212. 1944.

gram of research on Atlantic coast agar resources. One outcome was the discovery that a new type of agar can be prepared from the extractive of *Hypnea musciformis* (Wulf.) Lamour.[7] The important properties of this agar, gel strength and temperature of gelatin, can be altered or controlled over a wide range by addition of certain salts, sugars or other solutes.

Development of Agar Industry in Other Countries

Production of agar from *Ahnfeltia plicata* (Hud.) Fries and of an agaroid from *Phyllophora rubens* (L.) Grev. began in Russia about 1930. *Phyllophora*, abundant in the Black Sea near Odessa, apparently was the first to be utilized. *Ahnfeltia* is found in abundance in the White Sea, especially in the vicinity of Vladivostok, Archangel and Vladimir, cities of the far eastern provinces. *Ahnfeltia* agar is of good quality, but it is not produced in as great a quantity as *Phyllophora* agaroid. As in the United States, these pre-war Russian industries immediately expanded in 1942. Russian scientists have published many reports on technology, manufacturing processes, chemical nature and properties, and on the various uses of Russian agar and agaroid.

In 1942 production of agar began in many other parts of the world, particularly in Australia, New Zealand, South Africa and India. An abundant supply of *Gracilaria confervoides* in Australia near Sydney, in Moreton Bay, and in Big Lake near Yamba provides raw material for a thriving industry. Over 40 tons of agar were expected to be produced during 1946[8], and plans call for expansion to a capacity of several hundred tons per annum within the next few years. Australia consumed about 71 tons of agar in 1938, all of which was imported from Japan. Australian *Gracilaria* agar is said to be satisfactory for culture media and to have somewhat greater gel strength, elasticity and transparency than pre-war Japanese *Gelidium* agar. Another report states that Australian agar has a slighty lower gel strength than the Japanese product. The temperature of gelation of the two is about the same (37° to 42° C.).

As early as 1939, government laboratories in New Zealand began to consider the suitability of domestic seaweed for agar production. Four species, *Pterocladia lucida* (R. Br.) J. Ag., *P. capillacea* (Gmel.) B. & T., *Gelidium caulacantheum* J. Ag. and *Gracilaria confervoides*, have been tested.[9] The first mentioned species is the principal source because of its greater abundance, large size and relative ease with which it can be collected and processed. *Pterocladia* agar is said to be as good as Japanese *Gelidium* agar in all important properties, and better with respect to gel strength. New Zealand is apparently producing as much agar as was consumed in the islands in pre-war years.

The agar industry developed in South Africa in 1942, utilizing the cosmopolitan *Gracilaria confervoides*[10]. Other species, including *Gelidium cartilagineum* and *Suhria vittata* (L.) J. Ag., have been found to contain agar but do not occur in sufficient abundance or are difficult to collect in quantity. *Gelidium pristoides* (Turn.) Ktz. and *Hypnea spicifera* (Suhr) Harv. were also tested and found to produce a weaker gel than the others.

In 1941 the Laboratories of Industrial and Scientific Research in India investi-

[7] DeLoach, W. S., Christine Wilton, H. J. Humm, and F. A. Wolf. Bul. 3, Duke University Marine Station. 1946.

[8] Makaroff, A. Food Ind. **18**: 1545–1548. 1946.

[9] Moore, Lucy B. New Zealand Jour. Sci. & Tech. **25**: 183–209. 1944.

[10] Isaac, W. E. Jour. So. Afr. Bot. **8**: 225–236. 1942.

gated the possibilities of agar production from a species of *Gracilaria* (*confervoides*?) that grows in abundance along the coasts of Travancore State[11]. Two grades of agar, commercial and bacteriological, are produced. A yield of 43% of the dry weight of the seaweed is claimed.

In Italy the presence of agar in a red alga of the genus *Spyridia* was reported in 1940, although no reference was made to its abundance or utilization[12]. A weak gel was also prepared from *Grateloupia* that was said to be suitable for bacteriological purposes in a concentration of five percent.

Mexico has been an important source of raw material for California agar factories for a number of years. During the war, however, a factory was completed there. Agar production has been reported also in the Dutch East Indies and Straits Settlements.

Uses of Agar

Agar was originally used in the Orient solely for food. Before the discovery of its value as a gelling agent for bacteriological culture media in 1882, small quantities of it were shipped from Japan to Europe where it was used principally in making jellies or blanc mange. As a result of her experience with agar as a substitute for gelatin in the kitchen, Frau Fanny Hesse, the wife of an associate of the famous German bacteriologist, Robert Koch, suggested a similar substitution for culture media[13]. The idea was communicated to Koch who discovered that agar had many advantages over gelatin for culturing bacteria, and he published his observations in 1882. Soon thereafter bacterologists everywhere were using agar, and this new use led to a rapid increase in the quantities exported from Japan. The use of agar in bacteriology is still its most important use with respect to human welfare, although only about 15% of the agar consumed in the United States during the ten years before the war was for bacteriological purposes.

Western peoples became familiar with agar first as a gelling agent for food in place of gelatin, and later through its use in culture media. As a result of this introduction to America and Europe, many other uses soon developed. Today the uses of agar comprise a long and varied list, most of which were developed in America. New uses are constantly being announced. A detailed discussion of agar uses has been published by Tseng[14].

In Foods. As an ingredient of food, agar is rapidly gaining in popularity with manufacturers of frozen desserts, confections and baked goods. Large quantities are now used by bakers in fruit cakes, pie fillings, icings, meringues and certain types of bread. In fruit cakes agar is valuable as an agent for retaining moisture over long periods of time. In icings and frostings it prevents absorption of moisture during damp weather, with resultant stickiness, and prevents hardening during dry weather. In meringues and pie fillings it serves as a gelling or stiffening agent.

In sherbets and water ices agar is an excellent stabilizer. For chocolate milk, carrageenin is the best known stabilizer, while with ice cream, sodium alginate is preferred.

Agar is frequently used in cheeses, especially those of the Neufchatel type in which it reduces exudation of whey, renders the product easier to cut and gives it a firmer texture. Agar has been

[11] Bose, J. L., *et al.* Jour. Sci. & Ind. Res., India. 1: 98–101. 1943.

[12] Cioglia, L. Ric. Sci. Pro. Teen. Econ. Naz. 11: 179–181. 1940.

[13] Hitchens, A. P., and M. C. Leikind. Jour. Bact. 37: 485–493. 1939.

[14] Tseng, C. K. In J. Alexander, Colloid Chemistry, Theoretical and Applied. 6: 629–734. 1946.

recommended also as a means of increasing the digestibility of cheeses.

Probably as much agar is used in confections in the United States as in culture media, especially for making jelly candies and marshmallows, but in other types of candy as well.

In mayonnaise and salad dressings agar may be used as a stabilizer and thickener. In canned meats, especially fish, poultry and tongue, agar or an agaroid is used to prevent the product from becoming mushy as a result of vibration in transit. Gelatin is less satisfactory because it melts during warm weather. Agar also prevents certain meats from causing a de-tinning of the inside of the can and subsequent darkening of the product. One of the principal uses for agar in Australia and New Zealand is in canned meats for export.

Agar is often used in place of pectin for making jellies, jams, marmalade and preserves. It does not require a certain proportion of sugar and fruit acid to gel, as does pectin. However, the acidity of the fruit juices or pulp must not be greater than pH 5.5, or agar will be hydrolyzed when heated and fail to gel. For gelling acid substances, an agar solution should be prepared separately in water and mixed with the fruit product after both have begun to cool.

When used in foods in place of gelatin, agar offers the following advantages: it solidifies quickly, it does not have to be refrigerated, it will not melt at room temperature, and only about one-eighth as much agar is required.

Medicinal Uses. Agar is best known to the layman as a remedy for constipation. For such use it is best taken in granular form with cereals or simply as a suspension in water. As a gel it is less effective. Its value in constipation stems from the fact that agar is virtually indigestible by man; hence agar particles constantly absorb moisture and swell as they pass through the body, providing an ideal form of bulk to promote peristalsis and elimination. Agar has been highly recommended as a therapeutic agent for chronic constipation in children. It is often added in granular form to bread, biscuits, cookies or cereal for this purpose.

Pills of various kinds are often coated with agar, especially where it is desirable to time or delay dissolution of the capsule or coating, or where there is need for a controlled rate of release of the medicinal agent.

FIG. 3. *Suhria vittata.* (*Courtesy New York Botanical Garden.*)

In Dentistry. Agar is used as the principal ingredient of a compound used by dentists to make impressions for plates. Agar is present as a gel in high concentration in this product. It is melted and poured into the mouth at a temperature that does not burn. Gelation occurs, however, at a few degrees warmer than body temperature. The

solidified mold can be bent or somewhat compressed in removal and the elasticity of agar causes it to resume the proper shape again. Agar is used in a similar manner in preparing molds for artificial hands and in other prosthetic work, and by sculptors for making impressions.

In Cosmetics. Agar often serves as a base for greaseless creams of various kinds, to stabilize emulsions, and to control moisture content in tooth pastes, shaving creams, hand lotions, deodorants, sunburn creams and other preparations.

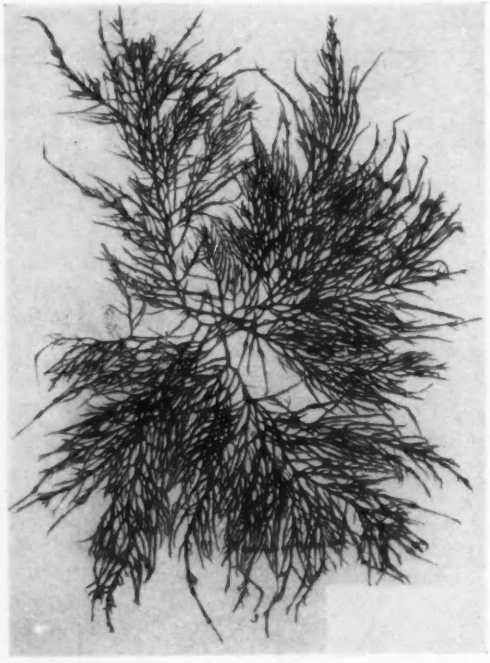


FIG. 4. *Agardhiella tenera.* (*Courtesy New York Botanical Garden.*)

Industrial Uses. In the manufacture of tungsten wire for light bulbs, agar is used as a suspending agent for graphite in a die-lubricating compound. It has been used in place of gelatin in photographic emulsions in which it has a number of advantages, but has never been widely used, probably because of the lack of uniformity of imported agar. Esters of agar are used, however, on the backing of films to prevent curling and reduce halation. These coatings wash off during developing.

Agar is used in hectograph duplicators, as an activator in nicotine sprays, in the electroplating of lead, in batteries for use in boats, and to coat humus particles for the marketing of nitrogen-fixing bacteria.

Agar and agaroids have been used to some extent for clarification of liquids such as wines, beer and liquors. In the Orient, it serves as a sizing for certain types of paper and fabrics.

In Science. In addition to its highly-important role in bacteriology, agar is one of the most important substances in studies on the physics of hydrophilic, gel-forming colloids. In chemical laboratories it is used to cause flocculation of barium sulfate precipitates. It is valuable to the microtechnician as an embedding medium for small pieces of plant or animal tissues that might otherwise be lost in solutions, and for cutting material with a freezing microtome. In studies of plant hormones, agar is used as a vehicle for the test substance in the *Avena* coleoptile method.

Manufacturing Methods

Since agar is readily soluble in boiling water, it can be extracted easily from seaweed. The resulting agar solution will form a firm gel when cool if the proper proportion of seaweed and water is used. Separation of the seaweed residue from the agar solution can be accomplished by simple straining, but removal of fine suspended matter is more of a problem because the viscosity and colloidal nature of agar, and the necessity of keeping the solution hot, make it rather difficult to filter. Filtration removes only the suspended impurities.

Soluble impurities can be removed from agar by freezing the gel and allowing it to thaw. As freezing occurs, most

of the water of hydration held by the agar micelles separates as free water. Upon thawing, water thus freed separates from the agar and takes with it the same percentage of soluble impurities as water lost from the original gel. The proportion of water set free varies somewhat with concentration of agar and species of seaweed from which the agar was extracted. Usually from 75 to 90% of the water is lost. Freezing and thawing are important steps in agar manufacture because of the two-fold effect: partial dehydration and a good degree of purification. The water remaining in the agar is removed by drying in the sun or in hot air. With agaroids, freezing and thawing are usually not practicable because so little water is lost.

American Factory Methods. A weighed quantity of dry seaweed adequate for one extraction is placed in a large tank of fresh water and washed by propellor agitation. It is then conveyed to a cooker. In California large pressure cookers are used; in North Carolina cooking is done in wooden tanks in which the water is heated by live steam. After two to six hours cooking, the agar solution is separated from the seaweed residue by straining and run into a storage tank in which a high temperature is maintained by steam coils. Usually the seaweed residue is cooked again and the resulting weak agar solution used as liquor in which to cook the next batch of new seaweed. Filter aid is added to the agar solution and it is forced through a filter press. In some factories a hypochlorite bleach is added to the agar just before filtration, but in others the bleaching agent is not added until later. From the filter press the agar solution is run into ice cans to cool and gel. After gelation has occurred, the agar may be chopped and then frozen, or it may be frozen in the cans without chopping. Blocks of agar ice are fed through a crusher and thence to a tank of water in which melting takes place. After melting is completed, North Carolina manufacturers drain the water off through a sieve and pump the wet agar to the drying room where it is spread on screens and dried by circulating hot air. It is hammermilled and pulverized and is then ready for market.

From the melting tank, California producers usually pump the agar-water mixture to a "dewaterer" which draws off the free water by vacuum, leaving the wet agar on a screen whence it is conveyed to a cylindrical stack drier through which a hot air current passes. As the moisture content of the agar flakes falls to 20%, they are buoyant enough to be blown to the top of the stack and are picked up by a screw conveyor. Some agar is marketed as flakes, but much of it is granulated by hammermill before it is packaged for use.

Japanese Method. The manufacturing process is similar in Japan but more primitive due in part to the low cost of labor. Dry seaweed as received by the factory is spread out in the sun again and alternately sprinkled with fresh water and allowed to dry until it is thoroughly bleached, a procedure necessary to obtain clean-looking agar where a filter press and filter aid are not used. Extraction is accomplished by open boiling, and often 20 to 40% of a cheaper substitute seaweed is added to the agarophyte, *Gelidium Amansii*[15]. The hot agar solution is strained through coarse and then fine mesh linen cloth and poured into wooden trays to gel. For shredded agar, the gel blocks are removed from the trays and cut into bars; then the bars are pushed through a grating to produce slender agar straws. These are spread on mats and allowed to freeze outdoors in the winter. When thawed and dried in the sun, the agar is pack-

[15] Tseng, C. K. In J. Alexander, Colloid Chemistry, Theoretical and Applied. 6: 629–734. 1946.

aged in the form of shreds. Since natural freezing is relied upon by most Japanese manufacturers, agar production is seasonal. Cooking is done only during late fall and winter. Seaweed is collected by fishermen during summer.

Physical Properties of Agar

Most investigators who have studied the physical properties or chemical structure of agar have worked with a commercially prepared product which they "purified". All commercially produced agar contains phycocolloids from a number of different species of seaweeds. Some Japanese agar may be as much as one-third extractive of a seaweed other than the principal agar source, *Gelidium Amansii*. Agar manufactured in America is not contaminated intentionally, but it is impossible for the manufacturer to free his raw material of all foreign seaweeds. Consequently, much of the data on physical properties is of limited value because of the influence on results by contaminating phycocolloids. To be reproducible and accurate, investigations must begin with the seaweed raw material, correctly identified by an algologist and carefully freed of all contaminating material before extraction of the phycocolloid is done. Any appraisal of the significance of literature on the properties of agar must take these facts into consideration.

Hysteresis. A phenomenon exhibited by agar to a remarkable degree is hysteresis, the lagging of response behind the application of some change causative of the response. *Gelidium* agar must be heated to about 90° C. in order to dissolve it in water. Once dissolved, gelation does not occur until the temperature has fallen to about 40° or lower. If the resulting gel is heated, it will not melt until the temperature is about 80°. Thus there is a range of at least 40° in which a solution of agar may exist either as a sol or as a gel. With North Carolina *Gracilaria* agar the range is only about 25°, since some samples begin to gel at about 60°, while the melting temperature is about the same as *Gelidium* agar.

The extractive from *Hypnea musciformis* is much more complex in its hysteresis behavior than any other phycocolloid known. In general, the temperature range between gelation and melting varies from 15° to 20°, a narrower range than for most phycocolloids. Since a solution of pure *Hypnea* extractive in distilled water apparently will not gel at any temperature in the absence of an electrolyte or some other solute, solutes, in addition to serving as gel-promoting agents, affect such characteristics as gel strength, temperature of gelation and melting, syneresis, viscosity of melted solutions, hysteresis and other physical properties. If potassium chloride is used to cause gelation, the temperature range between gelation and melting is about 16°; with rubidium or caesium chloride the range is about 18°; with dipotassium phosphate, 12°. Only preliminary observations have been made on the behavior of this phycocolloid.

Gel Strength. A recent study of gel strength of a variety of agars showed *Gracilaria confervoides* of North Carolina to produce the strongest gel[16]. If the gel strength given for this sample be assigned 100, the relative strength of other gels tested (all 1.5% agar) is represented as follows: California *Gelidium* agar, 69; South African *Gracilaria confervoides*, 52; Japanese *Gelidium* 42; California *G. confervoides*, 30; Australian *G. confervoides*, 26. Samples from which these gel tests were made are not necessarily representative, although a general trend is probably shown. Variation in gel strength of North Carolina *Gracilaria*

[16] Lee, C. F., and L. S. Stoloff. Spec. Sci. Rept. No. 37, Fish and Wildlife Service, U. S. Dept. of the Interior. 1946.

is such that the average is approximately the same as California *Gelidium* agar. Observations on gel strength of *Gracilaria foliifera* agar from the east coast of Florida indicate that it is about 90% as strong as the best *Gelidium* agar[17].

The remarkable effect of solutes on the gel strength of agar from *Hypnea musciformis* is such that gels can be prepared from this extractive that will possess as much as twice the strength, in equal concentration, of any other agar known, provided the proper solute is present. Many electrolytes are known to increase the gel strength of certain phycocolloids, especially carrageenin, but the relative effect is much less than with *Hypnea* extractive.

Syneresis. One of the characteristics of all gels is the tendency to slight shrinkage and a concomitant squeezing out of tiny droplets of water. Gels of both *Gracilaria confervoides* and *G. foliifera* typically exhibit greater syneresis than those of *Gelidium* agar. Syneresis of gels of *Hypnea* has been observed only superficially, but it is known to vary with the nature and concentration of solutes present.

The liquid that exudes from agar gels contains a higher concentration of solutes than were present in the original sol[18], except when certain mixtures of salts are present. As gelation occurs, agar particles are believed to grow in size and to form a vacuolate system in which solutes become more concentrated in the liquid phase because of hydration of the agar micelles. Syneresis represents a small portion of the liquid phase that is forced to the surface by contraction. Syneresis varies inversely with concentration of agar in a gel, while solutes affect both rate and volume of exudation.

Imbibition. Studies on the absorption of water by dehydrated agar have led to a better understanding of its physical properties and have shown that the principal factors that determine the extent of imbibition and swelling when equilibrium is finally reached are initial moisture content and the nature and concentration of solutes. As imbibition occurs, heat is evolved.

The longer an agar solution is heated at 100° C., the less will the agar swell after dehydration followed by soaking in water[19], but at the same time, ultimate swelling is also affected in a curious way by the initial water content[20]. Totally dehydrated agar swells relatively little, but swelling is progressively greater with greater initial water content up to about 313 mg. of water per gram of dry agar, where swelling is at maximum. Beyond this point a relatively higher initial water content results in relatively less swelling. At the point where the initial water content is about 554 mg. per gram of dry agar, swelling is slight and a change in optical properties has been noted. Agar sheets or disks are transparent with less than 554 mg. of water per gram, while with greater moisture content they are opaque. Further observations of this nature are needed on agar of known source and from different species of seaweeds.

Solutes, both electrolytes and non-electrolytes, have a pronounced affect upon the extent of imbibition of agar. Various acids and bases are said to have about the same affect upon swelling at a given pH, the maxima occurring at pH 3.0 and 11.0. In dilute solutions of neutral chlorides, the swelling of *Gelidium* agar is greater than in pure water, but

[17] Williams, R. H. Proc. Fla. Acad. Sci. **8**: 161–170. 1945.

[18] Rossi, G., and A. Marescotti. Gazz. Chim. Ital. **63**: 121–127. 1933; *Ibid.* **66**: 223–227. 1936.

[19] Fairbrother, F., and H. Mastin. Jour. Chem. Soc. **123**: 1412–1424. 1923.

[20] Clarke, B. L. Am. Chem. Soc. Jour. **47**: 1954–1958. 1935.

if the concentration of chloride is about 0.1 N or greater the swelling is less than in water. Cations are of greater significance, but anions affect the process, especially in higher concentrations; both cations and anions exert an effect in the order of their place in the lyotropic series. The effect of ions upon the imbibition of *Gelidium* agar is apparently the reverse order of their affect upon swelling of *Hypnea* extractive. Agar exposed to ultra-violet radiation or x-rays swells less than untreated samples, probably because of partial hydrolysis caused by short wave length radiation.

Precipitation. If a melted agar solution is poured into a large volume of ethyl alcohol or acetone the agar is precipitated as a white fibrous mass. Alcohol-precipitated agar can be redissolved in cold water, if the precipitate is not permitted to dry, and a gel will form immediately following dispersion of the agar. If the precipitate is dried, it must be heated almost to boiling to redissolve. Precipitation by alcohol is a convenient method of purifying agar.

Agar sols are also precipitated by small quantities of tannin (as little as 1%) or by large quantities of very soluble electrolytes. Explanation of these phenomena is based upon the theory that agar particles are stabilized by both hydration and electric charge and that both these factors must be removed to effect flocculation[21].

Solubility in Organic Liquids. Agar can be dissolved in glycerin, ethylene glycol and other polyhydroxy alcohols. *Gelidium* and *Gracilaria* agars do not gel in these liquids unless at least a small amount of water is present. *Hypnea* extractive, however, forms a firm gel in the complete absence of water. Apparently the micelles of the *Hypnea* sol are more rapidly "hydrated" by molecules of the solvent. It seems likely that special uses for *Hypnea* extractive will be developed by virtue of its property of forming gels in such liquids.

[21] Kruyt, K., and H. G. B. de Jong. Kolloid. Beihefte 28: 1–54. 1928.

Chemical Nature of Agar

In recent years much progress has been made toward an understanding of the chemical structure of certain seaweed polysaccharides which include many of those collectively called agar. To speak of agar as a single substance of certain (if known) chemical structure is probably a mistake. It must be assumed that each species of seaweed synthesizes a chemically different type of phycocolloid until it has been shown that phycocolloids from two or more seaweeds are chemically identical. Since the term "agar" is applied to extractives from many different species of seaweeds, the chemical structure of agar can be given only in general terms that apply to all agar-like phycocolloids, unless the species is stated from which the agar was obtained.

It has been shown that *Gelidium* agar and certain agaroids are a sulfuric acid ester of a linear galactan that exists in nature as a calcium salt. The galactan, a very complex carbohydrate, is composed principally of *d*-galactose units but also contains *l*-galactose. Agar is readily hydrolyzed by heating with a dilute acid, after which the solution will reduce Fehling's reagent and in which galactose can be detected. The calcium of the agar molecule can be replaced with other metals such as potassium or sodium or even by organic bases such as aniline and alkaloids. The resulting agar retains its fundamental properties but does not behave in precisely the same way as natural calcium agar. By this means the influence of the nature of the metal ion on properties of agar can be studied. It has also been found that the sulfate ion can be replaced by chlorine or nitrate without destruction of the gel-forming property of agar.

Electrodialysis of agar removes all metallic ions leaving the free agar acid, a 1% solution of which was found to have a pH of about 2.4[22]. Neutralization of the acid restores its gelating property, but if free agar acid is heated, irreversible hydrolysis results.

The ash content of *Gelidium* agar varies from about 1.3% in highly purified samples to 3 or 4% in commercially prepared agar. Calcium sulfate is the principal constituent. The acid-insoluble ash is usually less than 0.5%, most of which may come from diatoms, either from the seaweed or from diatomaceous filtering material used in filter presses.

With the agaroid carrageenin and with *Hypnea* extractive the ash content is 20% or greater. Apparently the carbohydrate portion of the molecule is less complex in agaroids.

One of the ultimate goals in the chemical analysis of phycocolloids should be the chemical synthesis in the laboratory of substances with similar properties. When a chemist learns how to combine a simple sugar, a mineral acid and a base to form a carbohydrate ester with properties similar to those of agar, he will have shown the way toward the creation of a long list of products of value to human welfare.

[22] Hoffman, W. F., and R. A. Gortner. Jour. Biol. Chem. **65**: 371–379. 1925.

Utilization Abstracts

Oiticica Oil. The oiticica tree, *Licania rigida*, grows wild and to a height of 50 or more feet along rich river banks in northeastern Brazil, where for many years the oil obtained from its nuts has been used as a lamp fuel and for medicinal purposes. "More recently, mixed with resins, it has been used successfully for caulking boats. Processing of the nuts was primitive. The natives hulled the nuts, crushed the kernels in a hand mortar, then mixed the resultant mass with water and heated the mixture. The oil coming to the surface was skimmed off, then treated with hot water for many hours to purify it".

Demands for oil engendered by World War I induced the erection of extraction apparatus in Natal, and the oil extracted was used chiefly in the local manufacture of paint. In 1927 a factory was set up in Rio de Janeiro, and in 1929 another at Fortaleza which has since become the center of the oiticica-oil industry. Improved processing has rendered the oil suitable for use in paints and varnishes for cement, marine and metal surfaces.

Subsequent publicity and a drop in importations of tung oil from China increased the exports of oiticica oil from Brazil from 88 tons in 1934 to nearly 11,760 tons in 1945, about 95% of which came to the United States. Oiticica, a fast drying oil, has thus attracted attention as a highly successful substitute for tung oil in paints and varnishes, and very useful also in linoleum, inks, moisture-proof fiber board, brake-bands and metallic soaps, and as an improver of elasticity in rubber base products.

The pecan-like fruit of the oiticica tree has a yellow to black kernel, containing about 60% oil within a shell that is dull greenish when ripe. The crops are gathered, wholly from wild trees so far, from January through April, *i.e.*, during the rainy season, and the work is a peasant occupation under very primitive conditions involving transportation on burros.

By establishing penalties for felling oiticica trees and for picking unripe nuts, by prohibiting exportation of the seeds, and by supporting experimentation in the growing of oiticica trees and in technological problems of the oil, the Brazilian government has given support to this rapidly developing plant product from Brazil. (*W. N. Small, Brazil 20(8): 14. 1946*).

Cinchona Plantation in the New World

The pre-war Dutch East Indies monopoly of cinchona bark, source of quinine—the world's great febrifuge—is being challenged by the prospective results of extensive experimental plantings of the trees in Guatemala.

F. R. FOSBERG

U. S. Department of Agriculture

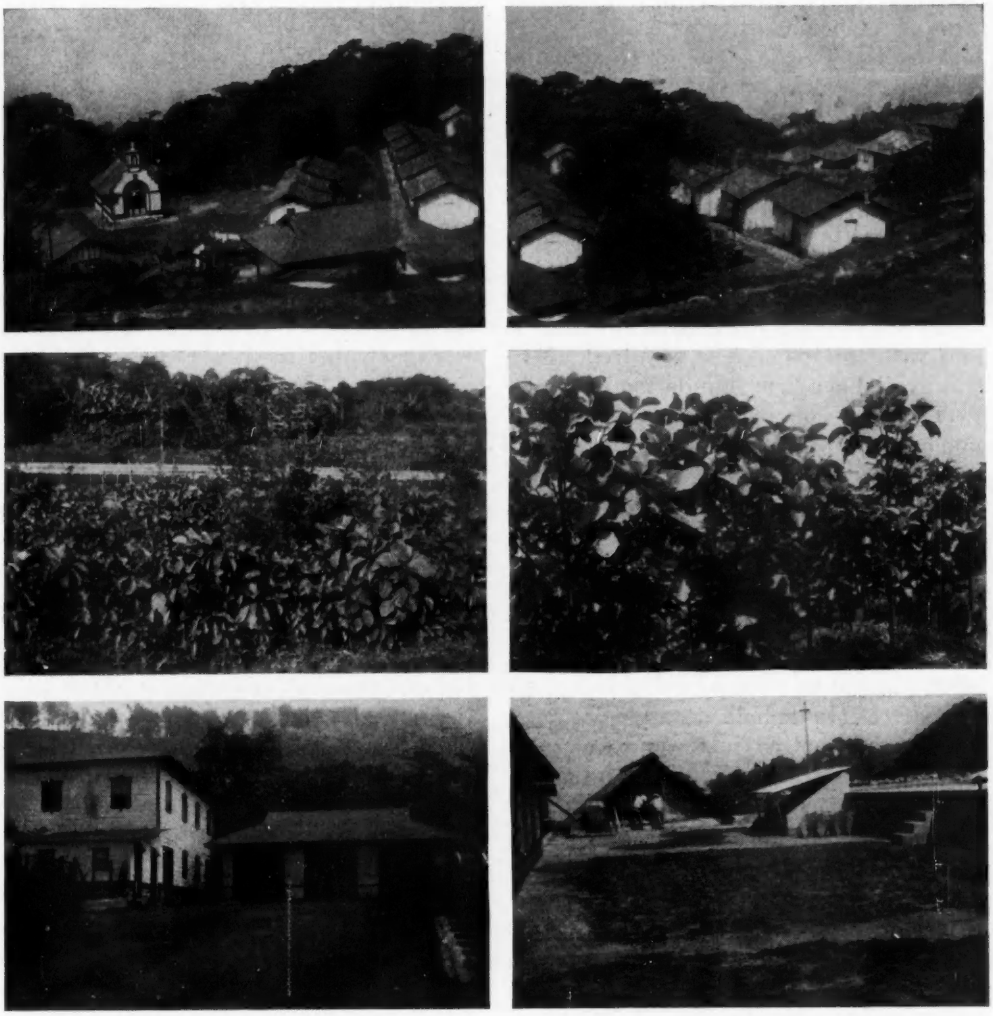
On the steep slopes of the extinct volcano Santa Clara, in southwestern Guatemala, a plantation may be visited where a fascinating experiment is taking place. It is an attempt to break the New World's dependence on the East Indies for a supply of cinchona bark, source of quinine.

In 1934, long before most people imagined the events of late 1941 and early 1942, when the cinchona plantations of the Far East were to be lost to the Japanese, American drug manufacturers were chafing at the quinine monopoly of the Dutch Kina Bureau. The shrewd cinchona planters of the Netherlands Indies had organized to protect themselves in their enjoyment of the fruits of their long and intensive research on the culture of this valuable tree. There had been many discouraging years of attempts at the establishment of plantations in the East, and many introductions of the trees were made from the New World. When finally, as a result of the introduction of the famous Ledger strain of cinchona from Bolivia, the plantations in the Orient became paying propositions, a supply of quinine to replace the rapidly vanishing wild product was assured. There followed a tremendous amount of research on methods of culture, harvesting of bark, and treatment and processing. Few other tropical crops have had such an amount of careful scientific work as cinchona. Then, in order to avoid over-production, with a consequent decline in price, the Dutch planters organized and effected a careful supervision of the amount of bark produced. The prices remained high, out of reach, of course, of the millions of impoverished malaria sufferers in the tropics, and the industry prospered.

During the years from 1900 to 1943 the amount of cinchona bark produced in America, the original home of the plant, was negligible. Small amounts of wild bark harvested in Bolivia were bought up by agents of the Kina Bureau. Occasional shipments of a low-quinine bark from northern Peru were sent to Europe for wine-flavoring. A few shipments of low-grade bark were made from Ecuador in recent years, and tiny dooryard plantations of the famous Succirubra variety of cinchona have existed for many years on the western slopes of the Ecuadorean mountains, but all without any influence on the world supply of quinine.

In 1934 Merck and Co., large scale American drug manufacturers, decided to attempt the promotion of cinchona cultivation in the New World. The technique adopted was to import seeds of desirable strains and to assist and encourage local coffee planters to undertake its cultivation. Guatemala was decided upon as the country in which to try the experiment. Though it may

have seemed almost hopeless to try to overtake and compete with the Dutch, with their 75 years of experience and operated well, but mistakes and discouragements were numerous and costly. Gradually a large number of strains of



Scenes at Finca El Naranjo, the Experimental Cinchona Plantation of Merck & Co. on the slopes of extinct Santa Clara volcano in Guatemala.

FIGS. 1 & 2 (*Upper left and right*). Church and laborers houses. FIGS. 3 & 4 (*Center left and right*). Seedlings and young trees of the Succirubra type of cinchona. FIG. 5 (*Lower left*). Two of the plantation buildings. FIG. 6 (*Lower right*). Quills of cinchona bark, stripped from trees, spread in a patio to dry in the sun.

research, as well as their tight organization, the company considered it a good long-term investment.

The planters worked hard and co- cinchona from many sources were accumulated and selection programs started. Experience was being acquired.

In 1939 Merck and Co. decided to go

further into the business and, under their auspices, Experimental Plantations, Inc., was organized. Finca El Naranjo, a large coffee plantation southwest of the beautiful Lake Atitlan, overlooking the Pacific slope of Guatemala, was purchased to be used for large scale experiments in the culture of cinchona. Together with the planters already engaged in the business they formed an organization for mutual assistance and cooperation in research called "Cinchona Cooperators of Guatemala". With the work already done by the planters, the selections of plant material accumulated, and with the experience acquired, there was available a firm foundation on which to broaden out experimentation on a much larger scale and even for practical production. The second world war, with the temporary loss of the Dutch colonies in the East, gave the enterprise just the impetus it needed. The planters were encouraged to broaden their operations. Experimental Plantations has acquired several smaller properties, as well as a large plantation in a wild and inaccessible part of Guatemala near the Mexican border and another in Costa Rica.

Finca El Naranjo is a large and thriving establishment. A staff of expert horticulturists and plant breeders with trained Guatemalan assistants live permanently on the place. There are comfortable houses for the staff. The climate is ideal, as the altitude is about 4,000 feet and cool breezes have a free sweep in from the Pacific. There are a shop and store, road and telephone connections with the rest of the country, and a thriving colony of local Indian laborers who are provided with a neat little village of sanitary and adequate houses. Also, and very important in the tropics, there is a clean, pure and abundant water supply from the slopes of the volcano above.

On the steep dissected slopes above the plantation headquarters are field above field of young cinchona trees of various ages. These fields, the plots and rows within them, and even many of the individual trees bear numbers or other designations. These are the keys to the careful records of the experiments kept in the offices.

There is an enormous nursery, with row upon row of beds of seedling trees, and literally miles of transplant beds. Grafting is performed to the extent of literally hundreds of thousands of plants in a season. This grafting of plants with a high quinine content but delicate constitution on rootstocks of vigorous weedy strains greatly reduces the hazards due to losses and poor growth.

The plants chosen for large-scale propagation are the products of a long and ruthless process of selection. Out of thousands of progeny of "mother trees" known for their high quinine content, only the very best are saved. As soon as the young trees reach an age where the quinine content of their bark is significant, samples of each are taken for analysis. Of the trees sampled, only the few with the very highest percentage of quinine are permitted to be the parents of the next generation. This process is repeated again and again. The very best trees are preserved and propagated vegetatively to form the clones, or asexually multiplied individuals, which are to be the basis of further experiments and of the commercial plantations to come. Much of the work of this selection process was accomplished by the original planters before the founding of Experimental Plantations.

Both before and during the war every effort was made by Merck and Co., the planters, the U. S. Department of Agriculture, and many individuals to bring together an enormous collection of kinds and strains of cinchona from every source available. Seeds were purchased or stolen in Java, brought from the more or less abandoned attempts at cinchona

planting in the Philippines, from German experimental plantations in Africa taken over during the first world war, from stations in the Belgian Congo, Brazil, confiscated Japanese plantations in Peru, from many wild trees on the slopes of the Andes in South America and in Costa Rica, as well as from trees still remaining in Guatemala from the days when President Justo Barrios made a vigorous attempt to establish cinchona there in the 1880's. The result is a wonderfully adequate supply of material for selection and development of the basis for the future industry.

The start already made in Guatemala gives every indication that American ingenuity and ability at scientific tropical agriculture is fully equal to that of the Dutch. There seems little doubt that when the dust settles in the East Indies and world commerce returns to something nearer normal the quinine monopoly will have been broken. The plantations in the New World and the Old may well settle down to normal healthy competition. Furthermore, enormously valuable lessons in tropical agricultural methods will have been learned and may then be applied to many other crop plants in the tropics which badly need development.

Utilization Abstracts

Tanning Materials. Up to about 50 years ago native hemlock [*Tsuga canadensis*] and oak [*Quercus montana*] barks were the principal native sources of tanning material in the United States, and great quantities were exported as well as used domestically. Those sources were succeeded by chestnut wood [*Castanea dentata*] which now is the only commercial source of natural tannin in the country, but which also is dwindling, to such a degree that 60% to 70% of the natural tannin required in the United States today is imported. In 1945 quebracho [*Schinopsis Lorentzii* and *S. Balansae*] extract from Argentine and Paraguay and wattle [*Acacia* spp.] extract and bark from Africa were imported to the extent of more than $12,800,000. Of less importance were mangrove [*Rhizophora Mangle*] from Africa, dividivi [*Caesalpinia coriaria*] and tara [*Caesalpinia tinctoria*] from South America. Now that the war is over, sumac [*Rhus coriaria*] may be expected from Italy, valonia [*Quercus Aegilops*] from Greece and Turkey, cutch [*Uncaria Gambir*] from Borneo. Eucalyptus [*Eucalyptus* spp.] extract from Australia is also a good substitute for the vanishing American chestnut. During normal prewar years, about 4½ million pounds of sumac were imported annually from Italy for use in light leather tanning and as a mordant in the dyeing of leather, cotton and silk.

To supplement these foreign sources of tanning extracts, collection and cultivation of various plants in America offer possibilities, provided the economic problems of production, harvesting and processing are solved. There are, for instance: American sumac [*Rhus glabra* and *R. typhina*] leaves, considerable quantities of which were harvested up to 25 years ago each year in Virginia for manufacture into extract for dyeing and tanning; canaigre [*Rumex hymenosepalum*], a possible farm crop, the roots of which contain up to 35% tannin when dried and were used for centuries by Mexicans and American Indians for tanning leather; experiments looking toward commercial production of this root have been undertaken at various times; badan, *Saxifraga crassifolia*, probably not yet tried in America but cultivated and used in Russia since 1890 where it is native.

A recent investigation of plants native to the United States as possible tannin sources recommended only buttonwood [*Conocarpus erectus*] and Darling plum [*Reynosia septentrionalis*] both of which require a Florida climate for good growth. (*A. Schubert, Chemurgic Digest 5(15): 265. 1946*).

Kenaf—*Fiber-Plant Rival of Jute*[1]

In India and other parts of the Old World kenaf has long been of value in the manufacture of gunny cloth, cordage, fishing nets, floor matting and rug backing, and since 1941 investigations have been conducted toward its cultivation in the New World.

JULIAN C. CRANE[2]

Introduction

ALTHOUGH interest in the kenaf plant as a source of soft fiber has developed in the western hemisphere mainly within the last five years, fiber from this plant has been used in other parts of the world for many years. In 1911 it was reported (27) that kenaf fiber was used in larger quantities than jute (*Corchorus capsularis* L.) for local use in India, the country which produces the world's supply of jute fiber. The plant has also been commercially exploited in Java for several years, where the fiber, "java-jute", is woven into sacks for use in the sugar industries. Russia in 1935 (48) had 32,500 acres of kenaf in production for fiber purposes. Considerable attention in that country has been directed towards determining the cultural requirements of kenaf, developing methods of extracting the fiber and adapting processes for spinning and weaving the fiber. In addition to the countries mentioned above, kenaf has been grown for fiber also in Persia, Reunion, Senegal, Nigeria, Natal and Egypt.

At the beginning of the second World War, various agencies of the United States Government began investigations, both domestically and in the tropical and subtropical regions of this hemisphere, to determine which of several fiber plants could best be produced to satisfy the great demand for soft or bast fiber needed for the war effort. Investigations in the United States (19) and in Cuba (9) showed that greater yields of fiber were obtained per unit area of land from the kenaf plant than from the several other plants studied. As a consequence, a research program was initiated by the United States Department of Agriculture to determine the cultural requirements of kenaf, as well as to devise mechanical methods for harvesting the plants and processing the fiber. The results of these investigations are summarized in this paper, together with world-wide information obtained from a comprehensive review of the literature dealing with the kenaf plant and its products.

Description and Nomenclature

Kenaf, since its distribution in 1941 throughout the American tropics by the Board of Economic Warfare of the United States Government, was erroneously referred to as "roselle", *Hibiscus Sabdariffa* var. *altissima* Hort. However, work in Cuba (10) definitely established its true identity as kenaf, *H. cannabinus* L. As a result of the misidentification of the plant, considerable confusion exists with respect to litera-

[1] The investigations involved in assembling this review were made possible by funds provided through the United States Interdepartmental Committee on Cultural and Scientific Cooperation.

[2] Assistant Professor of Pomology, University of California; formerly Horticulturist, Office of Foreign Agricultural Relations, United States Department of Agriculture.

ture references. Several references, especially from this hemisphere, deal with "roselle" when it was determined later that the plant material discussed was actually kenaf. It is true that plants of these two distinct species are quite similar upon casual observation, but, by close comparison, the differences as set forth in Table 1 are apparent.

Kenaf, usually an annual but under certain conditions a perennial plant, belongs to a large genus containing fiber-yielding species. The genus *Hibiscus* is in the family Malvaceae, of which cotton (*Gossypium* spp.) is probably the most important member. The *Hibiscus* genus is characterized by plants that generally have large showy flowers, the rose mallow (*H. Moscheutos* L.) and okra (*H. esculentus* L.) being representative American species. The plants of this genus abound in practically all countries, and to find a fiber list that does not include from one to several species is difficult.

TABLE 1

COMPARATIVE DIFFERENCES BETWEEN HIBISCUS CANNABINUS AND H. SABDARIFFA

Plant part	*H. cannabinus*	*H. Sabdariffa*
Flower:		
Bracteoles	Not adnate to calyx	Adnate to base of calyx
Color of corolla		
Fresh	Pale yellow to sulphur	Pale yellow
Withered	Pale yellow to sulphur	Pale yellow with reddish tinge
Seed:		
Shape	Triangular, angles acute	Rounded-hemispherical, angles rounded
Surface	Dull gray with many yellowish brown, raised spots	Dull gray without spots
Hilum	Yellowish brown, relatively small	Brownish red, relatively large
Stem	Prickly	Unarmed

The most valuable species of the genus is, according to Dodge (15), *Hibiscus cannabinus*, which, he states, is a native of the East Indies; some writers (25, 32, 40) are of the opinion that the plant is native to Africa, while another (45) says its home is Asia and Australia.

Miyake and Suzuta (33) have compiled a list of 129 world-wide names which have been given this plant. The Sanscrit name for the cultivated plant of ancient India, which produced Deccan hemp, was "nalita" (52). According to the first accurate information on kenaf fiber (43), the source plant is known in western India as "Ambari" (hence the names "Ambari fiber" and "Ambari" or "Ambaree hemp"), whereas in Madras it is known as "Palungi" and in Bombay as "Deccan hemp". In Hindustan (17) the plant is called "patsan", while in Bengal it is known as "Mestapat". The name "Kanaff" is used in Persia. It has been pointed out (26) that many of the names, such as "Indian hemp", "brown hemp", "Bombay hemp" and "Roselle fiber", were names for mixed-fiber products that were obtained not only from *Hibiscus* spp. but also from *Cannabis sativa* L., *Crotalaria juncea* L., *Abelmoschus* spp., *Urena* spp., etc. At the beginning of the twentieth century the pure fiber of *H. cannabinus* was called "Gambo hemp" or "Bimlihemp" (a shortened form of Bimlipatam hemp), and the name "Java-jute" had come into use.

In addition to the above names, the plant has also been called "wild stock

rose", "teel", "wild saur", "Hemp mallow", "Sunn Okro", "hemp-leaved *Hibiscus*", "Kanaf", "Bastard jute", "Deccani hemp", "Deckanee hemp" and "Deckanse hemp". Among some of the other names mentioned, the fiber products have also been called "Mesta fiber", "Dekanee hemp", "Jute of Madras", "Bimlipatam jute" and "Bimli-jute".

Varieties

Until 1911, when five varieties comprising eight agricultural types of *Hibiscus cannabinus* were selected and described in India (27), the kind of plant always referred to in the literature was the green-stemmed type with divided leaves. As a result of this comprehensive botanical investigation, the following varieties were named and typed:

"1. Variety *simplex*
Type 1.—Stems purple; leaves entire with purple petioles.
2. Variety *viridis*
Type 2.—Stems green; leaves entire with green petioles.
3. Variety *ruber*
Type 3.—Stems red below, greenish above; leaves divided with green petioles.
4. Variety *purpureus*
stems purple; leaves divided with purple petioles.
Type 4.—Late, stems very tall and slender; leaves with narrow lobes of a diffused purple color; petals purplish.
Type 5.—Early; stems short and robust; leaves green with broad lobes.
5. Variety *vulgaris*
stems green; leaves divided with green petioles.
Type 6.—Plants very early.
Type 7.—Plants late; seedlings with reddish stems.
Type 8.—Plants late; seedlings with green stems."

Work in Cuba (10) has shown that the *Hibiscus cannabinus* grown for fiber in this hemisphere is composed of two varieties: *viridis* (type 2) and *vulgaris* (type 8). As the seed which was introduced into Cuba from El Salvador was reported to have come originally from commercial plantings in Java, it is logical to assume that the varieties in Cuba are representatives of those grown in Java. Two of these, *viridis* and *vulgaris*, have been identified; the other, *purpureus* (26), has not been ascertained.

The following description of the two varieties in Cuba is presented for a basis of comparison:

PLANT.—Herbaceous annual of 3–7 months duration, depending on time of planting.

STEM.—Straight, simple, more or less glabrous but with prickles; 3–14 feet in height, depending on time of planting.

LEAVES.—Cordate and very shallowly lobed with serrated margins, mid-vein with one gland beneath near base of blade, petioles generally longer than the blades, with prickles slanting toward the blade; stipules linear and pointed.—*Hibiscus cannabinus* var. *viridis* (type 2). Basal leaves cordate and not lobed, 3-, 5- and 7-palmately lobed into narrow serrate parts, respectively, up the middle portion and 3-palmately lobed into narrow serrate parts at top of stem; mid-vein with one gland beneath near base of blade; petioles generally longer than the blades, with prickles slanting toward the blade; stipules linear and pointed.—*Hibiscus cannabinus* var. *vulgaris* (type 8).

FLOWERS.—Solitary, with short peduncles in axils of leaves; corolla large, spreading, thickened below and thin above, petals pale yellow to sulphur-colored with crimson to purplish center; epicalyx stiff, consisting of 7–8 bracteoles, 10–13 mm. long, which are free above, connate below, and inserted near base of calyx; calyx bristly, lanceolate, 29–31 mm. long, connate below the middle, 5-parted with one large gland near the middle; style rises through staminal column, one in number which terminates in 5 stigmatic branches; carpels 5, joined into 5-locular capsule, each locule containing 4 or 5 seeds; capsule bristly, globose, pointed; seeds glabrous.

The preceding descriptions indicate that these two varieties are alike in all external characteristics except shape of leaves. Investigations (46) on the percentage of natural cross-pollination in the different varieties have shown, how-

ever, that *viridis* is entirely self-pollinated, while in *vulgaris* cross-pollination varied from 2.6 to 3.9% in its various strains.

Observations on the two varieties in Cuba have indicated that they are composed possibly of a number of strains, in that there has been some variation in the period of vegetative development among plants. For example, in one particular planting there were a few outstanding plants which were green and had retained all their leaves, while, at the same time, the remainder had dropped most of theirs and seeds had matured. Similar observations have been made in Russia (3) where it has been found that the variety *vulgaris* consists of a number of strains differing by their length of growth period, by

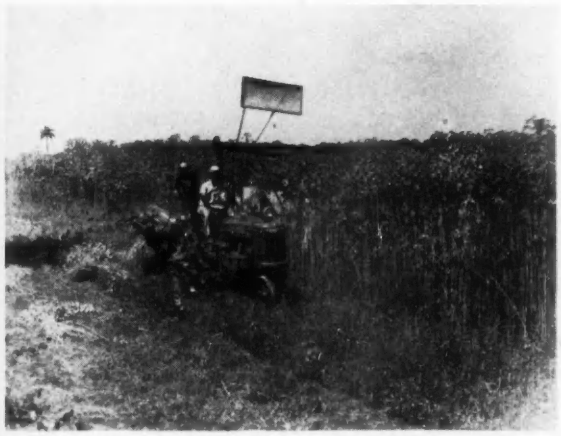


FIG. 1 (*Upper left*). 100-day-old kenaf ready for harvesting, planted in 8-inch drill rows, 30 pounds of seed per acre. FIG. 2 (*Upper right*). Kenaf may be harvested mechanically at the rate of approximately one acre per hour. FIGS. 3 & 4 (*Lower left & right*). 100-day-old kenaf stalks, cut and tied by a modified hemp harvester-binder, being loaded for transport to a de-fibering mill.

their habit of growth and branching, and by some other less important peculiarities connected closely with length of the vegetative period.

Work in Persia (41) has shown that the differences in strains of *Hibiscus cannabinus* are in the height of the plant, thickness of the stem, the color, and in the leaves and flowers. Strains were found with large and small seed capsules, and with large and small seeds. It was further noted that the earlier the strain, the closer to the ground the first flowering node was located; in the late strains, however, flowering began on the upper nodes.

The variations in strains within a particular variety might provide means of improving the plant for fiber purposes by selection in the field for one or two of the most obviously worthwhile characters, such as height of the first capsule and length of the stem. Some of the characters which an ideal fiber plant should possess are long thin stems, no branches, rapidity of growth and high fiber percentage with uniform length and strength. As this species is naturally self-pollinated, progress in breeding should be rapid and easy.

Cytogenetics

From the small amount of existing information there appears to be considerable disagreement regarding the chromosome complement of *Hibiscus cannabinus*. Some authors report the species to be a diploid, whereas others have found it to be a tetraploid. Ford (20) offers the explanation that possibly *H. cannabinus* may be composed of diploid and tetraploid races, as is its close relative *H. esculentus*, reported by Skovsted (44). The former and Narasinga Rao (37) found the chromosome complement of kenaf to be $2n = 72$, whereas the latter and Breslavetz *et al.* (5) found it to be $2n = 36$.

All crosses between the varieties and geographical races of *Hibiscus cannabinus* belong to the type of "congruent" crosses and are successful (31). From a study made by Medvedeva (31), the following data were obtained:

Plant material	$2n=$
H. cannabinus	
var. *purpureus*	36
var. *ruber*	36
var. *viridis*	36
var. *vulgaris*	36
var. *simplex*	36
H. Sabdariffa	
var. *altissima*	72

By treating the apical meristems of young diploid ($2n = 36$) kenaf plants with colchicine solution or with morphaline-colchicine emulsion, tetraploid ($2n = 72$) plants of the species were obtained (2). It was observed that the diploid and tetraploid plants resembled each other closely, but the latter showed a higher percentage of pollen sterility and had broader and thicker leaves. The offspring of diploid and tetraploid plants possessed about the same rate of growth. The theory was advanced that fibers of induced tetraploids may have greater length and diameter than those of the diploids from which they have been obtained (2).

Anatomical Portion of Plant Used for Fiber

The fiber obtained from the stems of *Hibiscus cannabinus* varies from five to ten feet in length (15). Each filamentous strand of fiber is composed of cells, their ends overlapping, which vary considerably in size but average about five millimeters long and 20 microns wide. These cells form collectively the principal part of the bast layer which gives strength and flexibility to the stem. This layer is the innermost portion of the bark and is located immediately outside the central woody cylinder and thin cambial layer.

FIG. 5 (*Upper*). 15-day-old kenaf in foreground; 100-day-old plants in background, ready for harvesting. FIG. 6 (*Lower*). The author examining kenaf fiber decorticated by a "Krupp" machine ordinarily used for henequen leaves.

Climatic, Photoperiodic and Soil Requirements

Kenaf is capable of adapting itself to a large variety of climatic and soil conditions (6), although, since it is sensitive to frost, it is best grown in tropical and subtropical locations. Early maturing strains (3) have been selected so that the plant can be grown under the conditions existing in central Asia. Extensive experiments (48) have proved that the northern limit of the plant is 45° north latitude. Kenaf is not uncommon in the lower Himalayas up to an elevation of about 3,000 feet (4, 7, 50). Areas where the plant is to be grown should be free or protected from strong winds (21, 53), since the growth is rapid and the plants get so tall that they cannot stand much wind. Extremely heavy rains are also detrimental in that they beat down the plants, and difficulty in harvesting results.

From 20 to 25 inches of rainfall over a period of four to five months is essential for the successful production of kenaf fiber (11, 26), this amount being less than is necessary for jute (18, 32). The wet period should be followed by a dry one in order that the fiber, after being extracted from the plant, may be dried and bleached in the sun. Although mechanical drying may, in the future, eliminate the necessity for sun-drying of the fiber, nevertheless, a dry period following the rainy season is necessary for the production of seed for successive crops of fiber. If rains occur during the time of seed maturation, the seeds germinate in the capsules before they can be harvested.

Along with the special requirement of climate, there is another factor which is of prime importance, inasmuch as the kenaf plant is photoperiodic and is influenced markedly by changes in length of the daily light period. This plant will not flower in Cuba (12), for example, until the length of the daily light period is shortened to approximately 12½ hours or less. A 12½-hour day length does not occur at that latitude (23° North) until the first part of September. Regardless of the time of planting, throughout the months from April to August, consequently, blossoming will not take place until September or October. This phenomenon in relation to time of planting for fiber and seed production will be discussed later in this paper.

A well-drained, sandy-loam soil, about neutral in reaction, with a considerable quantity of humus, appears to best meet the requirements of kenaf. On poorly drained soils the plant is seriously stunted and usually dies before producing flowers and seeds. Howard and Howard (27) pointed out that in certain sections of India kenaf is grown as a border crop on the edges of the fields where the soil is slightly raised and better drained than in the rest of the field. Use of light sandy soils for the production of kenaf is not recommended (21, 53), as plants growing in such soils bloom somewhat earlier, are short, and consequently give low yields of fiber. Since kenaf is very susceptible to nematodes, *Heterodera* spp., soils containing these organisms should be avoided.

Cultural Requirements

Kenaf responds well to good soil preparation (21, 27, 53). The soil should be deeply and thoroughly worked in order to provide a good medium for seed germination and to insure proper soil aeration for the seedlings that follow. Hard-pan layers close to the surface should be guarded against, since this condition retards growth and consequently reduces yields. Good soil preparation and cultivation are essential to the development of the plant because of its characteristic type of root system. Work in India (28) has shown that the tap root of kenaf grows comparatively

deep in the soil, and the development of laterals is not concentrated near the soil surface. Every effort should be made to insure a uniform germination of the seed and particularly an even stand of plants, so that there will be uniformity in the size of the stalks at harvest time.

A considerable quantity of humus in the soil is important for good production, and this can be supplied either in the form of manure or as green-manure crops (14, 26), both of which greatly stimulate the growth of *Hibiscus cannabinus*. *Crotalaria anagyroides* H.B.K., *C. usaramoensis* Baker, *C. juncea* L. and *Mimosa invisa* Mart. have been used successfully as green-manure crops. In Java (14) increases in fiber yields up to 50% have been obtained by using *M. invisa* supplemented with ammonium sulfate at the rate of 1,300 pounds per hectare (about 2.5 acres).

Time of Planting. Recommendations in the literature regarding time and rate of planting for fiber and seed are somewhat confusing, if not contradictory; but the discrepancies are the result of wide differences in environmental conditions and cultural methods employed in the various locations where the investigations were conducted. In view of the fact that the kenaf plant is extremely sensitive to changes in length of day, it is easily understood that the best time for planting in a location of a given latitude might not be successful in another location of a different latitude. Then again, the most suitable time of planting for fiber in one location might possibly be the best time of planting for seed production in another location, depending upon latitude.

Knowing the photoperiodic response of kenaf to varying periods of daylight, together with knowledge of the season of rainfall for a particular region, recommendations may be made as to the best time to plant for fiber as well as for seed production. In the production of any bast fiber it is highly desirable to have long clean stems free of branches or fruiting stalks which interrupt the continuity of the fiber. Planting of kenaf, therefore, must be done at the time of year when the days are of $12\frac{1}{2}$ hours duration or longer and remain that way over a period of three to four months. This is necessary in order to prevent flower bud initiation until after the plants reach a sufficient height to insure adequate yields of fiber per area of land. Using Cuba as an example, the days with $12\frac{1}{2}$-hour day lengths or longer comprise the months of April through August. Fortunately this period also includes the major portion of the rainy season. Planting for fiber as late as the middle of July to the last of August, however, does not give the plants sufficient time to grow vegetatively before flowering begins, and the crop does not reach ample height to produce profitable yields of fiber (13, 49). Planting as early as the first of April in some years would not be possible in Cuba, due to the fact that the rains might not begin until sometime in May. Therefore, plantings for fiber may be made from the beginning of the rainy

FIG. 7. Kenaf fiber as it comes from the decorticating machine.

season (April or May, depending upon local conditions) until the middle of July. Larger yields of fiber will be obtained from plantings made during the first part of this period than from plantings made later (13).

As the rainy season in Cuba generally ends about the last of October and as the day length is short enough to induce flowering during the months of September and October, the most reasonable time of planting for seed production is during the months of July and August. Higher yields of seed per plant have been obtained from July plantings than from August plantings (11). Planting in July, however, allows for approximately two months of vegetative development before flowering takes place; and, as a result, the bottom five- or six-foot portions of the stems are barren and contain no seed capsules. As plantings are made progressively later in the season, the portion of the stem which is barren becomes progressively smaller, but at the same time seed yields also decrease, due to the fact that the plants have a shorter period for development. If mechanical seed harvesting is to be used in the future, planting can be done any time during the months of July and August, depending upon the requirements of the machine and the nature of the plant material with which it will work to best advantage.

Distance of Planting. In general, the rather wide discrepancies in the literature with regard to proper distance of planting for fiber and seed production are the result, primarily, of the use of soils which varied considerably in fertility. For fiber production in Egypt (18) the seed is sown in hills eight inches apart, six seeds per hill, in ridges 21 inches apart. About 33 pounds of seed per acre are required using this method. After the seedlings have reached sufficient size, they are thinned to two or three per hill, according to the fertility of the soil. In Rhodesia (47) kenaf is sown by drilling in rows nine inches apart at the rate of 30 pounds per acre.

Workers in Java (14, 21, 32, 53) generally agree that the plants should be spaced six by six inches on the square, necessitating the use of from 13 to 18 pounds of seed per acre. Depth of planting is about one-half inch.

Recent work in Cuba (13) and El Salvador (49) has shown that the soils in those countries apparently can support a larger number of plants per unit area than soils in Java and some other parts of the world. Larger yields of fiber were obtained in Cuba from plantings made eight inches between rows and approximately two inches between plants in the row than from plantings with 16 and 24 inches between rows. This planting distance is equivalent to drilling the seed in eight-inch rows at the rate of 30 to 35 pounds of seed per acre. A somewhat larger area per plant is needed in El Salvador, as experiments there have shown that larger yields of fiber were obtained from plantings spaced two inches between plants in rows 12 inches apart than from several other planting distances tried (49). Planting by broadcasting at the rate of 38 pounds per acre has given good results; but, since a uniform stand of plants is particularly desirable, this method should be used with caution (53).

Since kenaf is harvested for fiber when the plants begin to bloom, a separate planting for seed is necessary for subsequent fiber crops. At fiber-harvesting time the custom has been, in many places, to merely leave uncut a portion of the field as a source of seed. This practice is not recommended, however, for two reasons. First, harvesting seed from a planting originally intended for fiber is difficult and costly. A fiber planting, if planted at the right time, grows vegetatively for a period of three

to four months before flowering begins. At blossoming time the plants may be nine to 12 feet tall, and the seed crop is borne on growth made subsequent to the initiation of blooming. At seed-harvesting time, therefore, the plants may have a total height of from 11 to 14 feet with, perhaps, the top two or three feet bearing seed capsules. Harvesting plant material such as this with a combine would be impossible. If, on the other hand, a separate seed plot is maintained, the time of planting can be adjusted so that plants of the desired height can be had at harvest time, with seed capsules at every node other than the basal foot or so of the stalk. In other words, depending upon the requirements of the harvesting machine used, the nature of the plant material with which the machine will work to best advantage can be controlled by the time of planting.

Using a portion of a planting originally intended for fiber as a source of seed is not desirable, secondly, for the reason that much lower yields of seed are obtained than from a planting made at the proper time and having a planting distance specifically for seed production. In previous discussion it was brought out how a plant with seed capsules borne practically the entire length of the stem, as compared with one having only from two to three feet of bearing surface, may be obtained by planting at a given time.

In Brazil (39) the planting distance used for seed production depends upon the method of seeding employed. When planting is done by hand, three seeds are dropped in each hill, 12×12 inches. However, when mechanical seeders are used, planting is done in continuous rows with a distance between rows of eight to 12 inches. Planting at this distance resulted in yields of only 180 pounds of seed per acre.

Choussy (8) states that in El Salvador kenaf for seed production should be planted between the middle of August and the last of September with 32 inches between rows and about 10 inches between plants in the row. Under normal conditions in El Salvador and in plantings which are well cared for, Choussy estimates the seed yield to be from 700 to 800 pounds per acre.

Dekker (14) in Java reports the planting distance used in that country to be 30 to 40 inches on a square, but no mention of yields is made from plantings of this nature.

Under Cuban conditions (11) 1,527 pounds of seed were obtained from a planting made late in August, using 20 inches between rows with one and a half inches between plants in the row. In comparison, plantings made 20×12, 24×14, 30×15 and 30×30 inches between hills yielded 597, 532, 371 and 343 pounds of seed per acre, respectively. It was pointed out that much larger yields of seed can be produced by planting in continuous rows 20 to 24 inches apart than by planting in hills at various distances. This planting method is readily adaptable to mechanization, as 12-row grain drills with eight inches between drills are already being used in Cuba in sowing kenaf for fiber production. In using these machines in planting for seed production, four rows, 24 inches apart, can be planted at a time by closing off the remaining drills.

Methods and Time of Harvesting. By planting in eight-inch drill rows, no cultivation or other care is required from the time of seeding to harvest. Kenaf is such a rank grower that it soon shades out weed competition. For seed production, where the rows are spaced farther apart, one or two cultivations may be necessary, depending upon seed bed preparation and weed population.

In harvesting, the custom has been to cut the plants by hand at ground level or to pull them up by the roots (6, 21, 43, 53). With one of the cut stalks used

as a string, the plants are tied into bundles, after which the tops with leaves are cut off. The slow and tedious process of harvesting kenaf by hand in this hemisphere is impractical and uneconomical because of the comparatively high wage rates. This problem has been solved, however, as a result of recent experimentation in Cuba (13). Mechanical harvesting investigations on a commercial scale, using a modified hemp harvester-binder, demonstrated that a crop of kenaf planted in eight-inch drill rows and which had grown to a height of 10 to 12 feet could be cut and bundled at the rate of an acre per hour.

Although some writers report to the contrary (14, 26, 43), the highest quality fiber is obtained when kenaf is harvested during the flowering period (18, 23, 50). As the percentage of fiber in the stem gradually increases until the time of flowering and then remains approximately the same (12), harvesting the plants either before or after this time would not be advisable. If done before flowering, lower yields of fiber are obtained, and if done after flowering, the fiber is of poorer quality (22, 50). With an increase in age of the plant, there appears to be an increase in coarseness and a decrease in lustre of the fiber. With the first formation of seed capsules on the stem, the fiber adheres to the pith more firmly than fiber in plants harvested earlier. It is generally agreed, therefore, that kenaf for fiber should be harvested during the flowering stage in order to obtain best results as far as yield and separation of the fiber from the stem is concerned.

Since the seed of kenaf matures progressively from the lower toward the upper portion of the plant, the best time for seed-harvesting, when done by hand, is when the seeds at the lower and middle portion of the bearing area are fully mature. The common method of harvesting kenaf for seed is to cut the plants by hand at the stage just mentioned and to shock them in the field for several days, so that seed at the top portion will have time to mature and cure before threshing. If harvesting by hand is delayed until all the seed capsules on the plant have reached maturity, then considerable seed is lost by shattering, especially from the lower portion of the seed bearing area. To thresh kenaf, the dried plants have usually been placed between large pieces of canvas and then beaten or flailed with long poles, after which the seed has been cleaned by winnowing. In Cuba and Honduras some threshing success has been achieved by running the dried plants through a rice thresher, and in El Salvador a coffee-threshing machine has been used for this purpose. It is expected that experimental trials to be conducted in Cuba this season will show the practicability of harvesting kenaf seed entirely by mechanical means. Since seed ripened on the plant before harvesting has proven to be better than that ripened in the shock (42), harvesting by combine would be desirable in that such a procedure would allow for seed-ripening on the plant.

Fiber Extraction

There are various ways to extract the fiber from kenaf stalks, all of which involve retting in water, except, of course, when power-driven decorticating machines are used. After the bundled plants have dried for two or three days in the field (26, 53), they are taken to a pond, irrigation ditch or retting tank and submerged in water. The length of the retting period, as reported in the literature, varies considerably from five to 22 days (6, 32, 40). This variation is caused, no doubt, by the greatly divergent environmental conditions under which the plants are grown, the differing stages of maturity of the plants at the time of harvesting, the different

kinds and temperatures of the retting water used, and the many other differing interrelationships that are not considered or controlled. The retting process is complete when the bark separates easily from the central woody cylinder and the fiber washes clean. At this stage the bundles of stalks are broken open and the fiber is stripped and cleaned by hand, after which it is dried in the sun. A skilled worker cannot strip more than 80 to 100 pounds of dry clean fiber in a day.

In El Salvador the cleaning process has been modified somewhat so that it is very similar to the method used in the United States for cleaning flax fiber. When the bundles of stalks are removed from the retting tank, they are shocked and left to dry in the sun. They are then passed between fluted rollers that revolve one above the other in opposite directions. This breaks up the central woody cylinder into little pieces. The material is then run through a beating machine which separates the wood from the fiber, leaving it quite silky and clean.

Large henequen—(*Agave fourcroydes* Lem.)—decorticating machines have been used successfully in Cuba to process kenaf. With the use of this machine the bundles of kenaf are brought directly from the field when harvested and put through the decorticator. The central woody cylinder, water and waste material from the plant are scraped away, leaving the clean fiber which is then dried in the sun for a day. The percentage of fiber varies with the age of the plant, but at the time of flowering the fiber comprises between 5% and 6% of the green weight of the stalks (13).

The capacity of the henequen-decorticating machine has been estimated at approximately 1,500 pounds of dried fiber an hour, which would require the stalks normally produced from about three-fourths of an acre. Consequently, to keep one machine in operation would require cultivation of kenaf on a large scale in order to be commercially practical. Experimental tests indicate, however, that the henequen-decorticating machine has promising possibilities for processing kenaf, and, since the harvesting is of short duration each year, the production of kenaf could well be worked into the henequen program.

Fiber Yield

The yield of fiber from *Hibiscus cannabinus,* as one would expect, is greatly divergent, depending upon the environment in which the crop is grown, the cultural methods employed, the conditions under which the stalks are retted or processed by machine, and other related factors.

Horst (26), in a study to determine the percentage of fiber in plants harvested at different growth stages and also the percentage of fiber in thick as compared with thin stems, found that in plants which were harvested to green (97 days after planting), a yield of 1.6% to 2% of fiber was obtained. When the plants were harvested at seed maturity, however, the yield of fiber amounted to 6.4%. He noted that the yield of high quality fiber was between these two figures, probably at 4% or 4.5%. The results of investigations in Cuba (13), on the percentage of fiber in different aged stems, showed a close parallel to data Horst obtained in Java. The percentage of fiber in the green defoliated stems increased from a low of approximately 2% when the plants were 40 days old to a high of slightly over 7% when the plants were 154 days old.

Fiber yields in India are reported to vary from 1,561 to 6,245 pounds per acre; in Senegal from 1,560 to 1,784 pounds per acre; while in Egypt average yields of about 3,123 pounds per acre are obtained (32, 40). In Nigeria (29) and Rhodesia (47) kenaf plantings on rich soils were reported to give a yield

of between 1,100 and 1,300 pounds of fiber per acre. In Cuba, by planting in eight-inch drill rows at the rate of 30 pounds of seed per acre, a planting made the first of May at the beginning of the rainy season yielded 5,805 pounds of dry clean fiber per acre (13). Plantings made at the same time in El Salvador, using a distance of 12 inches between rows and two inches between plants in the row, yielded only 1,224 pounds of fiber per acre. From these figures it must be concluded that the proper distance of planting and the subsequent yield of fiber are primarily dependent upon the fertility of the soil used in the production of kenaf.

The response of kenaf to the cultural methods discussed here exemplifies the possibility of producing this crop entirely by mechanical means. The comparatively high cost of labor in this hemisphere makes hand labor uneconomical, and mechanical seeders, harvesters and decorticators, therefore, will have to be relied upon if kenaf is to compete with jute fiber from India, a crop which is produced almost entirely by hand labor.

Disease and Insect Pests

In Java, Muller and van Eek (35, 36) report that the diseases which attack *Hibiscus cannabinus* are foot-rots which generally result in the death of the plant, and stem and leaf diseases which are of much less importance. Foot-rots are caused by *Pythium perniciosum* Serb., *Rhizoctonia solani* Kuehn, *Sclerotium rolfsii* Sacc. and *Phytophthora parasitica* Dast. The foot-rot caused by the last mentioned organism, according to these writers, is the most serious disease. It is described as a black basal rot, gradually merging into the sound tissue by way of an ill-defined water-soaked zone, and extending upward to a height, in severe cases, of three feet above ground level. In both these respects, according to Muller and van Eek (36), the *Phytophthora* rot differs from those due to *R. solani* and *S. rolfsii;* the discolorations induced are sharply differentiated from the healthy areas, and the height attained by the decay does not exceed two inches. Prophylactic measures should include soil sanitation, especially on sites of previous infection and around inlets of irrigation water.

Root knot nematodes, *Heterodera radiciola*, have been observed to be abundant in some plantings in Java (24). Likewise, the writer has seen considerable damage as a result of this pest in kenaf plantings in Cuba and El Salvador. Growth of infested plants is somewhat stunted and the leaves drop at or during the blossoming period. A rotation of crops, using one or more resistant types between successive plantings of kenaf, has proven to be an effective method of combating this pest.

Stem and leaf diseases of kenaf are of no great economic importance (36). *Phoma sabdariffae* Sacc. and *Cylindrocladium scoparium* Morg. cause some foliar spotting, sometimes accompanied by top rot, and local necrotic lesions on the stem cortex are produced by *Fusarium sarcochroum* (Desm.) Sacc., *F. coeruleum* (Lib.) Sacc. and *Diplodia* spp.

The only reference to insect pests of *Hibiscus cannabinus* which might cause some damage, especially to plantings grown for seed, is one made by Zegers Ryser (53). He states that *Dysdercus cingulatus* Fab. causes some loss by boring through the calyx and consuming the milky contents of the young seeds. No control for this insect is suggested except that the infested capsules should be removed and burned.

Characteristics and Uses of Kenaf Fiber and Seed

Kenaf fiber can be employed for the same purposes for which jute fiber is

used (15, 21, 26, 51). Several writers (16, 25, 27, 34, 50) agree that it is suitable for making coarse gunny cloth or sacking material, ropes and cordage of all kinds, fishing nets, floor matting, rug backing, *etc.* In some parts of India (16) the dry stalks of kenaf are split, tipped with a preparation of sulfur, and used as matches.

The ultimate fibers (single prosenchymatous cells of the bast), according to Biswis (4), vary from one and a half to four millimeters in length and are 12 microns in width at the middle. The thickness of the wall is four microns and the lumen is four microns broad. Biswis further states that the roughness and coarseness of the fiber are due to the nature of the encrusting substance, lignin. He found that the lignin is not entirely spread over the fiber, as it is in jute, which accounts for the difference in smoothness between the two fibers. In an experiment in which samples of kenaf and Bengal-jute were exposed two hours to steam at two atmospheres, followed by boiling in water three hours and again steamed four hours, the kenaf fibers lost 3.6% by weight, whereas the jute fibers lost 21.4%. He concluded that the kenaf fibers were tougher and stronger than jute because of the nature of the lignification.

Norman (38) states that the better known commercial fibers fall into two well-defined groups, one having only small amounts of xylan in the fiber cellulose, and the other having considerably more. The so-called fine fibers, such as flax and ramie, according to Norman, fall into the first group, whereas the coarser fibers, such as jute and kenaf, must be included in the second. In his study he found that kenaf fiber contained approximately half as much lignin as jute, 5.9% and 11.5%, respectively. Otherwise the two fibers were not very different in chemical composition.

In a study of *Hibiscus* fibers, Arno and Borschtschowa (1) found that two types of fibers exist in the stem of the plant, primary and secondary. They state that the division of the outer bast cylinder (the primary fibers) from the inner cylinder (the secondary fibers) is easily distinguished, since there are no anastomosing fiber bundles between the two cylinders. The primary fibers distinguish themselves from the secondary fibers by being firmer and more tightly packed together, by being glossier, more flexible, and by exhibiting other differences when used in the manufacturing processes. According to these authors, the differences in the two types of fiber are due to the origin of the fibers. The primary fibers (the first bast cylinder) appear to originate from the terminal meristem, or the vegetative point, whereas the secondary fibers arise from the cambium. The percentage of primary and secondary fibers in a given plant varies according to its height, but, on the average, there is about 38% primary fiber and 65% secondary fiber. With a decrease in stem thickness, an increase in the percentage of primary fiber was noted, whereas, on the contrary, with an increase in stem thickness, the percentage of primary fiber decreased. As far as spinning qualities are concerned, Arno and Borschtschowa preferred the early ripening varieties of *H. cannabinus,* since they were found to contain 56% primary fiber and 44% secondary fiber.

Kenaf seed yields up to 20% oil by weight of the seed, depending upon the extraction method used (29, 30, 32). It is stated that the oil is nonsiccative and, when refined, may be used for salads and cooking purposes. The oil, generally speaking, has about the same uses as cotton seed oil for which it could substitute with the advantage of having a somewhat milder odor (30). The residual cake may be utilized as cattle or poultry feed (29, 30, 32).

Summary

Kenaf, *Hibiscus cannabinus* L., is an annual or under some conditions a perennial plant belonging to the family Malvaceae. It is cultivated in many countries throughout the world for its bast fibers which are similar in chemical composition and physical properties to jute fiber of *Corchorus capsularis*. Five varieties, comprising eight distinct types, were selected and named in India several years ago. These five varieties, which appear to be representatives of the types of *H. cannabinus* grown in Persia, Russia, Cuba, Central America and other parts of the world, exhibit rather wide differences in the length of their growth period, in their habit of growth, and other peculiarities that are closely related to the length of the vegetative period.

Although kenaf appears to be adapted to wide variations in climatic and soil conditions, a well-drained, sandy loam soil, with a considerable quantity of humus, appears to best meet the requirements of the plant. From 20 to 25 inches of rainfall over a period of four to five months is essential to the successful production of kenaf fiber. Likewise for fiber production the length of the daily light period during the rainy season when the crop is grown should be of 12½ hours duration or longer in order to prevent flower bud initiation and subsequent blossoming until after the plants have reached a sufficient height to insure profitable yields of fiber.

For maximum yield of fiber per unit area of land, kenaf should be planted at the beginning of the rainy season. It is best planted by drilling in rows from eight to 12 inches apart, depending upon the fertility of the soil, at the rate of 30 to 35 pounds of seed per acre. For the production of seed, planting should be done from four to eight weeks before the length of the daily light period becomes shorter than 12½ hours. It is recommended that planting for seed production be done by drilling in rows 20 to 24 inches apart with two or three inches between plants in the row.

For highest quality fiber, harvesting is done shortly after the plants begin to bloom. The fiber, which is composed of cells forming collectively the principal part of the bast layer, or the layer which composes the innermost portion of the bark, is extracted by retting in water for several days or by large power-driven decorticating machines. Yields are variable, depending upon soil and environment, but generally a production of from 1,000 to 3,000 pounds of fiber are obtained per acre. A ton of seed may be obtained per acre if the proper cultural techniques are followed.

Hibiscus cannabinus is subject to foot-rot and stem diseases, the former being the most serious. Very few insect pests have been reported as attacking this plant.

Kenaf fiber may be employed in the manufacture of gunny cloth or sacking material, ropes and cordage of all kinds, fishing nets, floor matting, rug backing, etc. Kenaf seed yields up to 20% of oil which, when refined, may be used for salads and cooking purposes.

Literature Cited

1. Arno, A. and Borschtschowa, E. Vergleichende technologische Charakteristik der Fasern von *Hibiscus*, *Abutilon* und *Corchorus*. Faserforschung **11**: 79–99. 1934.
2. Badenhuizen, N. P. De toepassingsmogelijkheden van verdubbeling van het aantal chromosomen door middel van colchicine-behandeling bij tabak en Java-jute. Landbouw **17**: 231–251. 1941.
3. Berland, S. S. [The problems of breeding new fibre plants]. U.S.S.R. Cong. Genet., Pl. & Animal Breed., Proc. **4**: 49–66. 1930.
4. Biswas, K. Jute and allied fibres. Current Sci. (India) **3**: 571–572. 1935.

5. Breslavetz, L. *et al.* Zytologische Untersuchungen der Bastpflanzen. Zeits. Zucht. Reihe A, Pflanzenzuchtung **19**: 229. 1934.
6. Caldwell, S. A. G. Sunn and Bombay hemps. Textile Mfr. **62**: 455, 466. 1936.
7. Carter, H. R. Cordage fibres. 112 pp. 1909.
8. Choussy, F. Plan for the cultivation and exploitation of roselle in El Salvador. 1943. [Processed; copy in U. S. Dept. Agr., Off. For. Agr. Rel.].
9. Crane, J. C. and Acuna, B. Effect of planting rate on fiber yield of *Urena lobata* L. as compared with kenaf, *Hibiscus cannabinus* L. Jour. Am. Soc. Agron. **37**: 245–250. 1945.
10. ——— and ———. Varieties of kenaf (*Hibiscus cannabinus*), a bast fiber plant, in Cuba. Bot. Gaz. **106**: 349–355. 1945.
11. ——— and ———. Effect of plant spacing and time of planting on seed yield of kenaf, *Hibiscus cannabinus* L. Jour. Am. Soc. Agron. **37**: 969–977. 1945.
12. ——— and ———. Growth and development of kenaf, *Hibiscus cannabinus* L., with special reference to fiber content of the stems. Jour. Am. Soc. Agron. **37**: 352–359. 1945.
13. ———, ———, and Raul E. Alonso. Effect of plant spacing and time of planting on fiber yield of kenaf, *Hibiscus cannabinus* L. Jour. Am. Soc. Agron. **38**: 46–59. 1946.
14. Dekker, J. F. Java-jute en roselle. Landbouw **9**: 507–513. 1934.
15. Dodge, C. R. A descriptive catalogue of useful fiber plants of the world. U. S. Dept. Agr., Fiber Invest. Rpt. 9, 358 pp. 1897.
16. Duthie, J. F. and Fuller, J. B. Field and garden crops of the Northwestern Provinces and Oudh. Pt. 1. 1882.
17. Dymock, W. *et al.* Pharmacographia indica. 3 Vols. 1890–1893.
18. El Kilany, M. A. Jute and kindred fibres in Egypt; research and culture. Egypt Min. Agr., Tech. & Sci. Serv., Bul. 215. 1939. [In Arabic; Eng. sum.]
19. Ergle, D. R. et al. Malvacious bast fiber studies. Jour. Am. Soc. Agron. **37**: 113–126. 1945.
20. Ford, C. E. A contribution to a cytogenetical survey of the Malvaceae. Genetica **20**: 431–452. 1938.
21. Gorkom, K. W. van. Dr. K. W. van Gorkom's Oost-Indische cultures, opinieuw uitgegeven onder redactie van H. C. Prinsen Geerligs. 3 Vols. 1913.
22. Great Britain Imperial Institute. The cultivation of jute and similar fibres. Gt. Brit. Imp. Inst. Bul. **3**: 251–262. 1905.
23. ———. *Hibiscus* fibres from India and Iraq. Gt. Brit. Imp. Inst. Bul. **28**: 284–289. 1930.
24. Hartley, C. Notes on *Hibiscus* diseases in west Java. Phytopathology **17**: 25–27. 1927.
25. Holmes-Smith, E. Fibre plant investigations. II. Report of survey of the coastal districts of Natal Province. So. Afr. Jour. Ind. 2: 969–983. 1919.
26. Horst, W. Studien über den Gambohanf. Faserforschung **4**: 61–124. 1924.
27. Howard, A. and Howard, G. L. C. Studies in Indian fiber plants. No. 2. On some new varieties of *Hibiscus cannabinus*, L. and *Hibiscus sabdariffa*, L. Indian Dept. Agr., Mem., Bot., V. 4 (2). 1911.
28. ——— and ———. The economic significance of the root development of agricultural crops. Agr. Jour. India **12**: 17–28. 1917.
29. Kew Royal Botanical Gardens. *Hibiscus cannabinus* in Nigeria. Kew Royal Bot. Gard., Bull. Misc. Inf. **6**: 214. 1918.
30. Lewy, M. Kenaf seed oil. Jour. Am. Oil Chem. Soc. **24**: 3–5. 1947.
31. Medvedeva, G. B. Karyological review of 15 species of the genus *Hibiscus*. Jour. Bot. de l'URSS **21**: 533–550. 1936.
32. Michotte, Felicien. Les *Hibiscus* (Ketmie). Traité Sci. & Ind. des Plantes Textiles, Bul. Nos. 3–6. 1928.
33. Miyake, B. and Suzuta, I. *Hibiscus cannabinus* L. Formosan Agr. Rev. **368**: 591–597. 1937.
34. Mollison, J., ed. Note on the extension of cultivation of fibre plants in India. Agr. Res. Inst., Pusa, Bul. 15. 1909.
35. Muller, H. R. A. and Eek, Th. van. Aanteekeningen over eenige ziekten van roselle en Java-jute op Java. Landbouw **14**: 719–739. 1938.
36. ——— and ———. Aantheekeningen over eeinige ziekten van roselle en Java-jute op Java. Buitenzorg, Java. Inst. v. Plantenziekten. Meded. 92. 1939.
37. Narasings Rao, M. B. V. Chromosome numbers in two species of *Hibiscus* (*H. sabdariffa* L. and *H. cannabinus* L.).

Current Sci. (India) 4: 162, 175. 1935.
38. Norman, A. G. The composition of some less common vegetable fibres. Biochem. Jour. 31: 1575–1578. 1937.
39. Oliveira, A. C. de. Papoula de Sao Francisco (*Hibiscus cannabinus* L.). Bol. Min. Agr. 31: 1–10. 1942.
40. Pole-Evans, I. B. South African fibre plants. I. Ambari or Deccan hemp: *Hibiscus cannabinus* L. So. Afr. Jour. Ind. 1: 198–208. 1917.
41. Popova, G. M. A contribution to the morphology and biology of *Hibiscus cannabinus* L. Bul. Appl. Bot. 19: 493–496. 1928.
42. Poptsov, A. V. [Studies of the seeds of kenaph (*Hibiscus cannabinus* L.)] Kuban. Selsk. Khoz. Inst. Trudy (Kuban. Landw. Inst. Arb.) 8: 83–125. 1929.
43. Roxburgh, W. The plants of the coast of Coromandel. 3 Vols. 1795–1819.
44. Skovsted, A. Chromosome numbers in the Malvaceae. I. Jour. Genet. 31: 263–296. 1935.
45. Tobler, Fr. Bimli-Jute. Faserforschung 2: 225–232. 1922.
46. Ustinova, E. I. [Cross pollination in *Hibiscus cannabinus*.] Selek. i Semen. 6: 32–33. 1938.
47. Walters, J. A. T. Fibre-crops, Deccan hemp (*Hibiscus cannabinus*) and sunn hemp (*Crotolaria juncea*). Rhodesia Agr. Jour. 17: 522–528. 1920.
48. Wassermann, J. Recent investigations on the new bast fibers in U.S.S.R. Rayon and Melliand Textile Monthly 16: 146–148. 1935.
49. Watkins, J. M. Growth and fiber production of kenaf, *Hibiscus cannabinus* L., as affected by plant spacing in El Salvador. Jour. Am. Soc. Agron. 38: 978–982. 1946.
50. Watt, Sir George. A dictionary of the economic products of India. 6 Vols. 1889–96.
51. ———. The commercial products of India. 1908.
52. Wiesner, J. Doe Rohstoffe des Pflanzenreiches. 3 Ed. 3 Vols. 1921.
53. Zegers Ryser, W. A. Cultuur en bereiding van *Hibiscus cannabinus*. Vezelcong. gehouden te Soerabaia van 3 tot 8 Juli, 1911. Verslag, deel 1, 1. gedeelte, pp. 317–328. 1911.

Utilization Abstracts

Spanish Essential Oils. "Since World War I Spain has become a heavy producer of essential oils, *viz.*, spike lavender, rosemary, sage, thyme, origanum, pennyroyal, eucalyptus, marjoram, rue, cade and orange. Large quantities of these oils were yearly exported mainly to the United States and the United Kingdom, to a lesser extent to France, Germany and other European countries to be used primarily for the scenting of soaps, in medicinal preparations, for the flavoring of food products, and for technical purposes in general". The Spanish Civil War of 1936 to 1939 diminished this production, but the subsequent European war spurred it through the demands of other European countries, especially Germany. Today trade with the United States is gradually being resumed.

Spike or spike lavender, *Lavandula latifolia*, growing up to three feet tall, is not the same as lavender, but the volatile oil in the leaves resembles that of the latter, except that it contains some camphor. Only wild plants are used, gathered from alluvial soils as well as arid sun-exposed interior slopes up to 700 meters altitude in the temperate countries of the western Mediterranean—especially Spain, also southern France, and to a smaller extent in Italy and Dalmatia. Of these regions, Spain has long been the principal producer, as is true of all other essential oils discussed in this article. The arduous cutting, gathering and transporting of the wild plants in summer is performed by peasants at extremely low wages, and the oil is obtained by steam distillation of the foliage in crude movable field stills. At times, adulteration of the product as put on the market has been accomplished by addition of various adulterants, for example, pine oil and fractions from the manufacture of terpineol, Spanish sage oil, eucalyptus oil, and camphor oil. Similar adulterations are made with respect to all the other oils.

The greatest production of spike oil in Spain amounted to 125 tons for one of the years from 1928 to 1936. A small amount is produced in France. Oil of spike lavender

is used principally for scenting soaps; less in cosmetic and technical preparations, bath salts, room sprays, disinfectants, *etc.* In general, it is a low-priced substitute of lavender oil.

Oil of rosemary is obtained from *Rosmarinus officinalis,* from the leaves and flowering tops. The plant is a small, evergreen, blue-flowered shrub native to Mediterranean countries, growing on limy, arid, sunny mountain slopes, especially in Spain, Dalmatia, Tunisia, Morocco and southern France. From 1931 to 1935 the annual production of Spanish rosemary oil varied from 60,000 to 150,000 kilos. Dalmatia, Tunisia and Morocco are secondary sources. Most of it is used for scenting soaps and technical products and for denaturing alcohol. It is used also in certain medicinal preparations, as an ingredient in liniments, in room sprays and in inhalants. The leaves are used as a condiment in European, especially French and Italian, dishes and sauces, and are considered emmenagogue and gently stimulant.

Spanish sage oil is distilled from *Salvia lavandulaefolia* and must be distinguished from the oil of *S. officinalis,* growing in Dalmatia, and that of *S. Sclarea,* cultivated in southern France and southern Russia. The Spanish sage occurs wild in several provinces of Spain. Production in Spain previous to the Civil War of 1936 varied from four to seven tons annually, and today may be up to ten tons. It is used principally in scenting soaps.

Numerous species and varieties in the genus *Thymus* grow wild in Spain, Morocco and other countries bordering the Mediterranean, and they all may be sources of so-called thyme oil. In Spain, the principal producer of the oil, *T. vulgaris* and *T. Zygis* are the main sources, growing up to a foot in height. The oil, "a powerful germicidal, finds wide application as a disinfectant and antiseptic of rather pleasant odor. It is used as such in many pharmaceuticals and oral preparations like gargles and mouth washes". It "is said to cause mental excitement", and "it serves as a diffusible stimulant in collapse". The oil is used also for scenting soaps and for flavoring various kinds of food products, *e.g.,* meats, sausages, sauces and canned foods. For these culinary purposes the dried plants are also used. In 1945 Spain produced probably 25,000 kilos of the oil.

Oil of origanum, frequently mislabeled as thyme oil, is distilled from *Thymus capitatus* [*Coridothymus capitatus*]. Spain, Palestine, Syria, Cyprus and Morocco are the principal sources. The anual production of origanum oil in Spain varies from ten to twenty tons. The oil is used in scenting soaps; in flavoring meats, sausages, sauces, canned goods, *etc.;* and as a disinfectant in oral and other pharmaceutical preparations.

Mentha Pulegium var. *eriantha,* which grows in southern Spain, is the source of oil of pennyroyal, used mainly in scenting soaps and, most of all, in the manufacture of synthetic menthol. The latter use became important during recent years, especially in Germany and Switzerland, when the supply of Japanese menthol, and of Javanese citronella oil, used for making synthetic menthol, were cut off. This demand for the substitute increased the production of Spanish oil of pennyroyal from about ten tons annually to about sixty tons in 1942.

Therapeutically pennyroyal is a gently stimulating aromatic, is recommended for treatment of flatulent colic and sick stomach, and promotes perspiration when administered as a warm infusion.

Thymus Mastichina, principally, and *T. Cephalotes,* secondarily, are the sources of oil of marjoram in Spain. The oil is consumed principally in the United States and is used for seasoning sauces, meats, sausages, soups, *etc.* It is to be distinguished from that of sweet marjoram (*Majorana hortensis*).

Most medicinal eucalyptus oil is supplied by Australia from several species of *Eucalyptus,* including *E. globulus* to a minor extent, but other amounts have come from Spain where only *E. globulus* is the source. The trees grow profusely in the southernmost part of the country, and in pre-war years Spain annually produced 60 to 100 tons of the oil; 300 tons in 1942.

One of the most useful and most important of all essential oils, oil of eucalyptus is an ingredient in lotions, ointments, inhalants, gargles, tooth pastes, disinfectants, room sprays, scrubbing powders, cleansers and soaps; also in cough drops, cough medicines and candies. (*E. Guenther, Am. Perf. & Essen. Oil Rev. June, 1945–April, 1946*).

Hemp. Since colonial times the long soft fibers of hemp [*Cannabis sativa*] have been important in the American manufacture of

twine, carpet thread, carpet yarn, sail cloth, homespuns, yacht cordage and oakum. To supply the demand much hemp was grown at home in the eighteenth and early nineteenth centuries, but never more than a fraction of what was needed. Cheaper foreign labor resulted in ever increasing importations from Europe and Asia until the maximum of 55,000 tons was reached in 1889. By 1900 competition from cotton and Manila hemp had reduced the American annual consumption of true hemp to less than 9,000 tons and importations of it to about 4,000 tons. In the 1920–1930 decade imports completely disappeared, and by 1933 the lowest figure of less than 50 tons of American grown fiber were produced. In the years just before the recent war this amount increased to about 600 tons yearly. Only two areas in Wisconsin and Kentucky were producing the material in 1940.

Then came World War II with increased demands for cotton and the loss of the Philippines, whence Manila hemp [*Musa textilis*] had come. As a remedial measure, to aid in meeting the demand for all fibers, the Hemp Division of the Commodity Credit Corporation of the U. S. Department of Agriculture was set up to revive domestic production of hemp fiber.

Through this agency 42 mills at a cost of more than $100,000 each were erected in hemp-growing districts of the United States, principally in Iowa, Minnesota and Wisconsin; least in Illinois and Kentucky. They obtained raw material from local farmers to whom seed was sold and machinery rented by the Federal Government. These growers had to be registered under the Federal Marihuana Tax Act of 1937 and licensed under State laws. By 1944 only 17 of the 42 mills were operating, and in 1945 it was announced that they, too, would close. Contracts with growers expired at the end of that year.

Hemp is an annual crop, requiring 80 to 140 days from planting to harvesting, depending on moisture and temperature conditions. Only the stalks of staminate plants, which grow to ten feet in height, are used; pistillate plants are serviceable only as seed producers. The machine-harvested stalks are retted in the fields from two to eight weeks, during which time the fibers become loosened from the rest of the stalks. The material must then be stacked for winter curing, and the fiber later separated in the mill. Only 20% of the straw is fiber. A modern mill with the services of about 80 employees can separate about 10,000 pounds of fiber per day, whereas in olden days, when much highly skilled hand labor was needed for all operations, one skilled worker could prepare about 250 pounds daily. Previous to the recent short-lived, government-sponsored boom, Kentucky was the principal hemp-producing State, furnishing 75% of the nation's output; the remainder came from Wisconsin, Illinois, Nebraska, Missouri, Texas and California. (*J. H. Garland, Eco. Geog. 22: 126. 1946*).